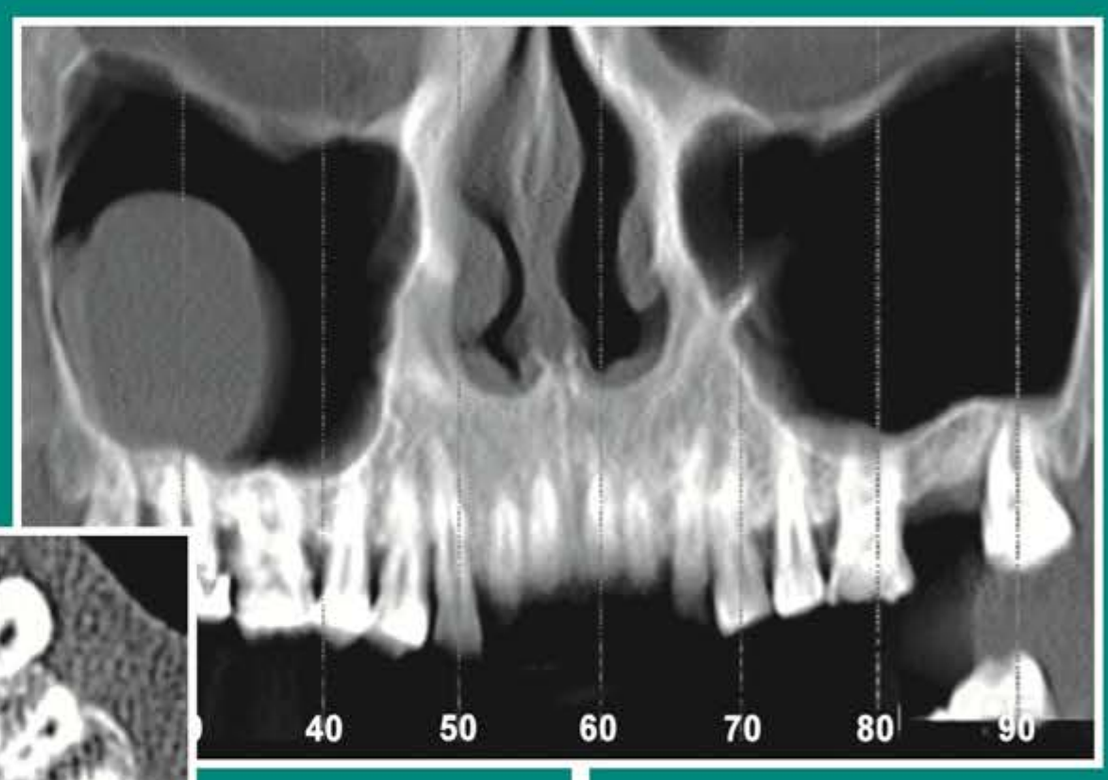
DENTAL CT

Third Eye in Dental Implants



Editor-in-Chief
Prashant P Jaju

Editors
Sushma P Jaju
Prashant V Suvarna
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Foreword
Stuart C White

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VISIT…

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Editor-in-chief

Prashant P Jaju BDS MDS
Senior Lecturer
Department of Oral Medicine and Radiology
Mahatma Gandhi Vidyamandir's
KBH Dental College and Hospital
Chief Radiologist
3D Facial Imaging Center
(Cone-Beam CT Scan Center)
Nashik, Maharashtra, India

Editors

Sushma P Jaju BDS MDS
Conservative Dentistry and Endodontics
Consultant Endodontist and Private Practitioner
Dentocare Multispecialty Dental Clinic
Nashik, Maharashtra, India

Prashant V Suvarna BDS MDS
Professor and Guide
Oral Medicine and Radiology
DY Patil Dental College and Hospital
Pune, Maharashtra, India

Pratik Dedhia BDS MDS
Senior Lecturer
Oral Medicine and Radiology
Terna Dental College and Hospital
Mumbai, Maharashtra, India

Foreword

Stuart C White

JAYPEE BROTHERS MEDICAL PUBLISHERS (P) LTD.

New Delhi • Panama City • London • Dhaka • Kathmandu

Jaypee Brothers Medical Publishers (P) Ltd.

Headquarters.
Jaypee Brothers Medical Publishers (P) Ltd.
4838/24, Ansari Road, Daryaganj
New Delhi 110 002, India
Phone: +91-11-43574357
Fax: +91-11-43574314
Email: jaypee@jaypeebrothers.com

Overseas Offices

J.P. Medical Ltd.
83, Victoria Street, London
SW1H 0HW (UK)
Phone: +44-2031708910
Fax: +02-03-0086180
Email: info@jpmedpub.com

Jaypee-Highlights Medical Publishers Inc.
City of Knowledge, Bld. 237, Clayton
Panama City, Panama
Phone: + 507-301-0496
Fax: + 507- 301-0499
Email: cservice@jphmedical.com

Jaypee Brothers Medical Publishers (P) Ltd.
17/1-B Babar Road, Block-B
Shaymali Mohammadpur
Dhaka-1207, Bangladesh
Mobile: +08801912003485
Email: jaypeedhaka@gmail.com

Jaypee Brothers Medical Publishers (P) Ltd.
Shorakhute
Kathmandu, Nepal
Phone: +00977-9841528578
Email: jaypee.nepal@gmail.com

Website: www.jaypeebrothers.com
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CONTRIBUTORS

Allan G Farman BDS PhD MBA DSC
Diplomate ABOMR
Professor, Radiology and Imaging Science
University Louisville School of Dentistry
501 South Preston Street
Louisville, Kentucky 40292, USA

Hemant Telkar MD DMRE
Infinity Imaging Center
Mumbai, Maharashtra, India

Prashant P Jaju BDS MDS
Senior Lecturer
Department of Oral Medicine and Radiology
Mahatma Gandhi Vidyamandir's
KBH Dental College and Hospital
Chief Radiologist
3D Facial Imaging Center
(Cone-Beam CT Scan Center)
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Oral Medicine and Radiology
DY Patil Dental College and Hospital
Pune, Maharashtra, India

Pratik Dedhia BDS MDS
Senior Lecturer
Oral Medicine and Radiology
Terna Dental College and Hospital
Mumbai, Maharashtra, India

Rajiv Desai MDS
Professor and Head
Department of Oral and Maxillofacial Pathology
Nair Dental College and Hospital
Mumbai, Maharashtra
India

Rakesh Jamkhandikar MD DMRE
Department of CT and MRI
Deenanath Mangeshkar Hospital
Pune, Maharashtra
India

Sanjay Jain MDS
Assistant Professor
Periodontics
Rangoonwala Dental College
Pune, Maharashtra
India

Stuart C White DDS PhD
Professor Emeritus
UCLA School of Dentistry
Los Angeles
USA

Sushma P Jaju BDS MDS
Conservative Dentistry and Endodontics
Consultant Endodontists and Private Practitioner
Dentocare Multispecialty Dental Clinic
Nashik, Maharashtra
India

FOREWORD

Cross-sectional imaging is an indispensible component in modern dentistry as it provides images through dental structures free of superposition of other structures and free of distortion. This book describes the various dental programs that have been optimized for dental applications of computed tomography. In particular, this book focuses on the utility of dental CT for implantology, oral and maxillofacial surgery, endodontics and periodontics. The book is well organized with a lot of attention paid to the basic principles and methods so that the readers will gain an appreciation of how to position of the patient and interpret the images to get the most from their examinations. Detailed description of the steps making for each examination is provided. There are many tables that allow the readers to quickly grasp the essential points. The qualities of the images are high and include both normal anatomic structures in the regions of interest and various common pathologic conditions.

In recent years, cone-beam imaging is starting to replace dental CT, while the focus of this book is exclusively on dental CT. The principles and examples of radiographic interpretation presented in this book are fully applicable to cone-beam imaging.

I commend the authors for their thoughtful work and recommend this book for everyone using dental CT.

Stuart C White DDS PhD
Professor Emeritus
UCLA School of Dentistry
Los Angeles, USA

PREFACE

As dentistry evolves within the digital age, manufacturers develop and introduce, and oral healthcare professionals continue to incorporate, technological innovations to enhance their practice, as well as improve predictability and productivity of day-to-day dental operations, especially dental implantology with prosthetic restoration of missing teeth.

It is now more that a decade since the first cone-beam computed tomography (CBCT) system, the NewTom (QR, Inc., Verona, Italy – now a Cefla company) received patent approval in Europe. That system required the patient to be placed supine, and in appearance, it mimicked fan-beam CT scanners used in medicine. The NewTom provided a low dose, reasonably affordable 3-D radiograph imaging system for use in the dental office. To that point, the third dimension in imaging had usually meant either blurry and magnified film-based linear tomograms or referral to a medical radiology office, where the CT system was focused at the whole body rather than the maxillofacial region, and the operators were not always cognizant of the diagnostic needs of dentists or the relatively high radiation exposure to the patient. Dental CT can be performed either by CBCT or by multi-slice CT, but the latter generally results in substantially higher doses to the patient.

CBCT systems now abound, both in numbers and variety, and are already quite common in dental practices and dental imaging centers throughout the world. There are supine systems (e.g. Cefla/QR NewTom 3G; Cefla/Myray SkyView), sit down systems (e.g. ISI/i-CAT; Gendex CB500; ISI/Soredex Scanora 3D; J Morita Accuitomo; Prexion 3D; 3M Iluma Elite) and stand-up units (e.g. Cefla/Newtom VG; J Morita Veraviewepocs 3D; Kodak 9000 and 9500; E-Woo/Vatech Picasso Trio; Suni 3D; Sirona Galileos). There are large field of view (FOV) systems that can be used in evaluating craniofacial anomalies and planning orthognathic surgery, where multi-slice CT would have been used previously, at much higher radiation dosages to the patient. Generally, such full FOV systems are employed at relatively low isotropic voxel resolution (i.e. 0.2–0.4 mm) to reduce the dose needed while reducing image noise, and also to permit reasonable reconstruction times.

At the other end of the spectrum, there are small FOV systems that usually provide higher resolution (i.e. often 0.1 mm isotropic voxel resolution or better) that are ideal for such situations as endodontic assessments. These small FOV systems may be hybrid, providing 2-D digital panoramic and/or cephalograms. Hybrid systems are available at less than US $90,000, a price comparable to an upper level 2-D pan/ceph not so many years ago, and perhaps less in constant dollar value. Small FOV systems can provide limited (i.e. “focused field”) volume images of several teeth for approximately the same dose as two traditional intraoral radiographs. Given that multiple such traditional images at different angles could be needed to evaluate an endodontic problem, small FOV CBCT might actually result in a dose savings to the patient.

CBCT is an adjunct to 2-D imaging in dentistry. The 3-D imaging provides a clear relationship between structures that could be obscure on 2-D images. CBCT is useful for assessing impacted teeth, particularly the relationship between mandibular third molars and mandibular canals. It is also valuable in assessing implant positioning and preimplant bone augmentation to provide the best possible prosthodontics reconstructive outcome.

Small FOV CBCT is valuable in assessing failed endodontics and perhaps also in primary evaluation of certain teeth prior to endodontics. However, CBCT does not replace 2-D imaging of dental caries. Beam hardening artifact from restorations and tooth enamel would result in a very large number of false positives for dental caries should current CBCT systems be used for caries detection.

While the recent graduates from dental school may have some grounding in 3-D imaging and direct experience with CBCT during their studies, this varies between institutions. Most dentists already in practice have limited or no training in using 3-D images for dental practice, and there are few existing pointers for optimizing CBCT patient

image selection. For this reason, this book is particularly useful for demonstrating the value of 3-D imaging for the specific purpose of dental implant planning.

While the average dentist should be able to fully understand the anatomic and disease findings from a small "focused field" image volume, there is still the need to train the dentist in Image Segmentation Methods in order to get the most out of the available information, even with these systems. With large FOV systems, careful review of the full information contained in the image volume takes more time and expertise. In such cases, it is probably most cost-effective for practitioners to refer the image volume out for a careful review by a specialist in oral and maxillofacial radiology. There can be many findings within the CBCT volume significant to the health of the patient, and such findings are particularly common in older individuals attending dentists for dental implant treatment. The individuals ordering and making the CBCT volumes are certainly responsible to make a full interpretation, just as they are with panoramic and other 2-D images. Practitioners are no less responsible for failure to diagnose with CBCT than with any other radiographic image. To indicate otherwise would be a disservice.

The 3-D imaging provides accurate anatomic relationships between structures and is much easier to explain—often with simulations—to the patient. One might not always be able to preserve the integrity of the mandibular canal when extracting a third molar, even given a 3-D image, but one is more aware of potential complications and best approaches. The patient also is better informed before consenting to the procedure.

There might be practitioners who have relied upon panoramic images to place dental implants for three decades or more, and these "gurus" often do not see any need to move from what they perceive to be success, until they experience 3-D images and see where they were actually placing the implants previously! After that enlightenment, 3-D imaging becomes the rule. One can teach an "old dog" new tricks, at least when it comes to dental implantology. This is a benefit for both the dentist and patient.

This book is aimed both at "old dogs" and "new dogs" to dental CT in implantology. It represents a welcome addition to the library of all practitioners interested in performing dental implant placement optimally.

Allan G Farman

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The book of this magnitude is possible only due to assistance and support from a considerable number of people. I am grateful to the pioneers in dental imaging in particular its utilization in implant imaging. I owe an enormous debt to the gifted implantologists and oral radiologists of this age, who seek to expand the envelope of their knowledge. They are my real contributors. The book is a culmination of many years of contemplating fundamental principles conveyed by early researchers, continually scrutinizing the literature to remain abreast of advances and refining illustrative material.

First and foremost, I wish to acknowledge the work of our esteem contributors their enormous efforts is highly appreciated. I feel privileged to have had the opportunity to work closely with such talented people. Particular acknowledgment is extended to Professor Emeritus, Dr Stuart C White and President of AAOMR, Dr Allan Farman for extending their sea of knowledge towards this textbook. Both the legendary oral radiologists had no apprehension in contributing towards this book.

Dental CT—Third Eye in Dental Implants would not have been possible without the guidance, support from M/s Jaypee Brothers Medical Publishers (P) Ltd, New Delhi, India. Each and every member of their team have exhibited exemplary professionalism along with a good sense of humor during this arduous task. I am also indebted to Mr Tarun Duneja (Director–Publishing) who encouraged us to write this book and saw it through from an idea to publication. I also wish to thank the production department of Jaypee Brothers Medical Publishers, who took the manuscript and some radiographs and created a true work of art.

I am also grateful and feel indebted towards Dr Hemant Telkar, Infinity Imaging Center, Mumbai, Maharashtra, India, and Dr Rakesh Jamkhandikar by providing the excellent cases which have been a useful teaching aids and also improved the sense of understanding of dental CT. I also wish to extend our gratitude towards the management of our respective colleges without whom this book would have not become a reality.

This textbook would not have been completed without the timely, valuable, knowledgeable and enthusiastic contributions of Dr Sanjay Jain, Dr Rajeev Desai, Dr Vaibhav Avinashe, Dr Jayaprakash Patil, Dr Shail Jaggi, Dr Reema Shah, Dr Arun Subramaniam, Dr Ajay Bhoosreddy, Dr Rajiv Gadgil, Dr Nipa Parikh, Dr Chetan Bhadage, Dr Seema Patil, Dr Ajay Nayak, Dr Shailesh Gondivkar and Dr Anuj Dadhich.

I also wish to thank the staff, postgraduate and undergraduate students of Mahatma Gandhi Vidyamandir's KBH Dental College and Hospital, Nashik; DY Patil Dental College, Pune; and Terna Dental College, Mumbai for their continuous encouragement and support.

Finally, I wish to thank our families. Their unwavering love, encouragement and moral support not only made our lives easier but also ultimately the most important force ensuring a successful result.

This is not merely a book of experiences with dental CT, but a combined effort of all of the above. Through their efforts, I hope that I have been able to describe the state of dental CT in implantology in present era.

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Chapter 1

Introduction to Dental Implants

Prashant V Suvarna

The real voyage of discovery consists not in making new landscapes, but in having new eyes.

Technology is fighting tooth and nails to restore health in its natural dynamics by sorting to biocompatible artificial substitutes. Implant dentistry is one of the most researched and technologically advancing modality for the treatment of partial or complete edentulousness. Experiments carried out by Branemark and co-workers at the University of Goteberg in early 1960s demonstrated that it was possible to establish a direct bone to implant contact and thereby they introduced the term "osseo-integration" into the field of dentistry. Later in the 1970s Shroeder et al. and Albrektsson et al. independently confirmed the occurrence of osseointegration and gave an impetus to the progress of oral implantology.

Ever since the concept of osseointegration has gained acceptance, the use of dental implants for replacing missing teeth has increased in leaps and bounds. Also with dental insurance coming into existence in the near future, the option of dental implants seems financially feasible, and subsequently an upsurge in the number of implants placed can be expected.

As we all know that with the advancement in medical technologies and geriatric care facilities, the overall longevity of patient's life is increased. This has brought out the ultimate desire in patients of living life to its fullest. This further propels this branch, of extreme research, into ultimate existence and widespread acceptance. Thus, the crux of implant dentistry is here to stay and thrive for long, as in other advanced countries. Planning, planning and planning remains the ultimate step that has to be given paramount importance prior to implant placement and is undoubtedly one of the "mantras" for success.

An astute clinician will fail if he does not take the help of the "third eye", i.e. the use of radiology for planning implant placement. Verification of radiographs, CT scan evaluation and advanced digitalization along with post pixel voxel combat results in the virtual image which is close to anatomical perfection. The quantity, quality, the bony concavities along with undercuts and neurovascular bundle and anatomic cavities like approximation to sinus can be closely assessed.

Conventional radiographic techniques are being commonly used by the dental practitioners to quantify and assess the available bone at the proposed implant site. The inherent distortion in the machine and the enhanced variations due to positional technical errors further magnifies the distortion which is not anticipated and taken into account ultimately leading to inaccurate readings and unwanted stress during the operative procedures.

The treatment planning and evaluation of proposed implant site most commonly is done by panoramic radiograph (OPG) by many although, trouble shooting in OPG for positional errors and incorporation of ball bearings in the radiographic techniques and thereby assessing the percentage of magnification becomes an important step which is not performed by the general dental practitioners **(Figs 1.1 and 1.2)**. Diagnostic information, treatment planning and treatment benefits levels have increased with the use of 3-D imaging techniques. Using 3-D virtual planning techniques before treatment has resulted in optimal implant placement and improved clinical outcomes. The development of 3-D scanning such as Dental CT, Cone-beam computed tomography (CBCT) instead of planar films has led to improved visualization and comprehension of the anatomy

Fig. 1.1 Panoramic radiograph suffers from inherent distortion and magnification

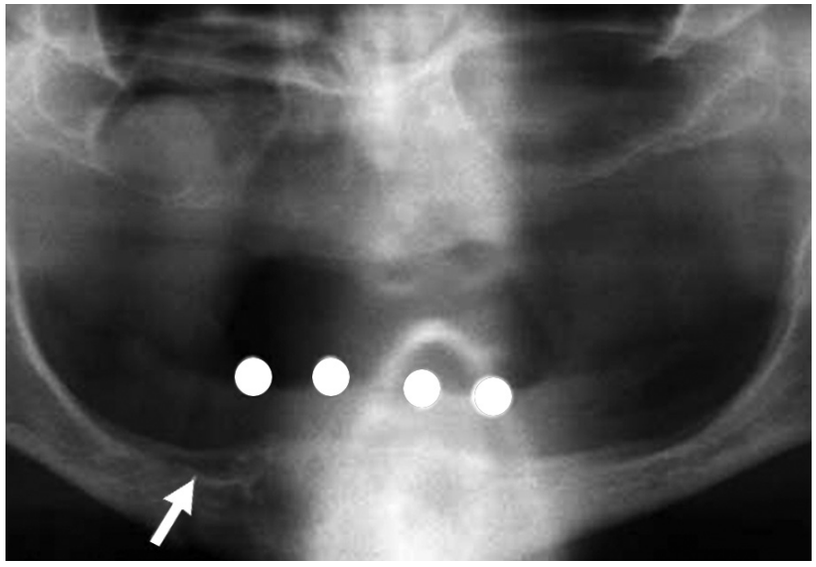


Fig. 1.2 Metal ball used in panoramic radiograph

in the areas in which implants are being planned for placement. Computed tomographic (CT) scans reproduce the anatomy with a submillimetric accuracy. A surgical guide can be designed and constructed on the basis of computer analysis of the available bone, the proximity of teeth to the proposed implant site and structures to be avoided in implant placement. This information can help clinicians comprehend better the optimal location of implant placement and ultimately lead to a better potential for a successful outcome. With such technological advancement at the disposal of oral implantologists, dental implants never looked so simplified.

Further chapters will add the pitfalls and nuances in implant imaging and make the journey of rehabilitation of edentulism with implant imaging as a paramount junction from where the further routes of treatment planning starts. So enjoy the journey from the start, embark on the destination but be sure that you choose the correct and the right path.

Many of life's failures are people who did not realize how close they were to success when they gave up—Thomas Edison.

So they say keep your head and heart in right direction, you will never have to worry about your feet.

Chapter 2

Conventional Imaging Techniques and Dental Implants

Prashant P Jaju

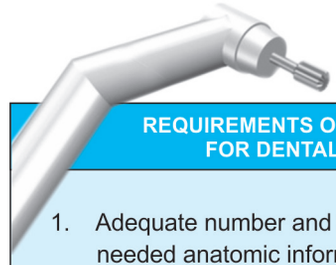
There are number of basic principles of radiography that should guide the clinician in selecting an appropriate imaging techniques and judging whether the resultant images are of adequate quality for the purpose.

1. There should be an adequate number and type of images to provide the needed anatomic information. This includes the quantity of bone, quality of bone as well as the location of anatomic structures, which generally requires multiple images at right angle to each other.
2. The type of imaging technique selected should be able to provide the required information with adequate precision and dimensional accuracy.
3. There must be a way of relating the images to the patient's anatomy.
4. Irrespective of the technique used, the patient, X-ray beam, and imaging receptor should be positioned to minimize distortion. In addition all images should have adequate density and contrast and should be free from artefacts that might interfere with interpretation.
5. The desire for preoperative imaging information should be balanced with the radiation dose and financial cost to the patient. If there is more than one technique suitable in a particular case, the ALARA (as low as reasonably achievable) principle should govern the selection.

IMPLANT IMAGING OBJECTIVES

Imaging for dental implants can be broadly be divided into three phases of the treatment **(Table 2.1)**:

1. Preoperative imaging
2. Surgical phase imaging
3. Postprosthetic imaging



REQUIREMENTS OF IDEAL IMAGING FOR DENTAL IMPLANTS

1. Adequate number and type of images to provide the needed anatomic information.
2. It should provide anatomical details with adequate precision and dimensional accuracy.
3. Way of relating the images to the patient's anatomy
4. Should be free from artefacts that might interfere with interpretation.
5. ALARA (as low as reasonably achievable) principle should govern the selection.

Table 2.1: Imaging modalities recommended according to the stage of implant treatment

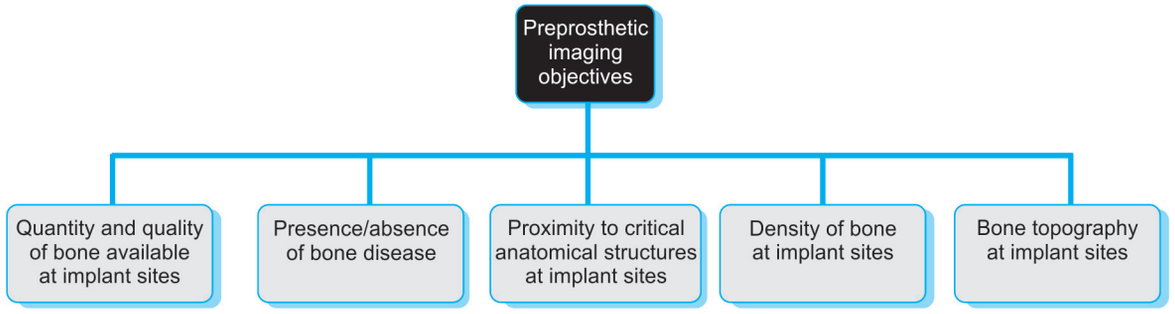
Phase of treatment	*Imaging modalities*
Preoperative imaging	IOPA, OPG, CT
Surgical phase imaging	IOPA, digital imaging (RVG)
Postprosthetic imaging	IOPA, digital subtraction
Postoperative complications	CT

Anatomic and Architectural Considerations

The objective of preoperative dental implant imaging is to gain the following information about the potential implant site **(Flow Chart 2.1)**:

1. Presence of disease.
2. Location of anatomic features that should be avoided when placing the implant, such as the maxillary

Flow Chart 2.1 Preprosthetic imaging objectives



sinus, nasopalatine canal, inferior alveolar canal, and the mental canal and the foramen.

3. Location of the osseous morphology, including knife edge ridges, location and depth of the submandibular fossa, developmental variations, postextraction irregularities, enlarged marrow spaces, cortical integrity and thickness, and trabecular bone density.
4. Amount of bone available for implant placement and the orientation of the alveolar bone.

In the past, patients desiring dental implants were evaluated with intraoral, panoramic, or cephalometric radiographs, tomography, or a combination of these methods.

The resulting images allowed the practitioner to examine the bony anatomic structures necessary for assessing potential implant sites.

The American Academy of Oral Medicine Radiology (AAOMR) recommends that evaluation of any potential implant site include cross-sectional imaging orthogonal to the site of interest. This information is best acquired with tomography, either conventional or CT. Conventional film tomographic views are most useful (free of streaking artifacts) when complex motions are used, such as spiral or hypocycloidal patterns, instead of linear movement. CT is most appropriate for patients who are being considered for many implants (8–10 or more) or when grafts or reconstructive surgery have been done or are being considered. The threshold for the number of sites that may need CT imaging depends on the type of conventional tomography system available. Nevertheless, the authors emphasize that currently there is no scientific evidence for that recommendation.

The below table summarizes the various imaging modalities available for implant imaging. Conventional imaging techniques which satisfactorily meets the preprosthetic imaging objectives are the periapical radiograph (IOPA) and panoramic imaging (OPG) **(Tables 2.2 and 2.3)**.

Intraoral periapical radiographs are very useful high yield modality for ruling out local bone or dental disease, but have limited value in determining quantity and in depicting the spatial relationship between the structures and the proposed implant site. In India there is a tremendous utilization of panoramic radiograph for evaluation of implant sites as it provides broad view of the maxillofacial skeleton. But it suffers from dimensional distortion both in horizontal and vertical dimension. According to Garg K, Vicari A (1995) distortion can be a major problem with panoramic radiographs, but when performed properly they can provide valuable information, and are both readily accessible and cost efficient. To help localize potential implant sites and assist in obtaining accurate measurements, it was recommended that surgical stents be used with panoramic radiographs. The panoramic image provides no information on bone width, which may be critical for implant placement in relation to the submandibular gland fossa, the sublingual gland fossa, the incisive fossa, the inferior alveolar canal, the maxillary sinus and the floor of the nose. Thus it can be concluded that panoramic radiography images provide a useful overview and may be used in conjunction with ridge mapping or other diagnostic tools, but they did not meet the strict criteria for a panoramic imaging test for implant planning.

Table 2.2: Advantages and disadvantages of various imaging modalities

Imaging modality	*Application*	*Cross-sectional information*	*Advantages*	*Disadvantages*	*Radiation dose*
Periapical	Individual implant sites	No	High resolution Low cost Ready availability	Distortion Limited size Limited reproducibility	Low
Occlusal	Individual implant sites. Mapping for multidirectional tomography	No	High resolution Low cost Ready availability Large area of coverage	Distortion No reproducibility	Low
Panoramic	Multiple sites Survey view of bony anatomy	No	Visualization of all anatomical structures. Low cost Ready availability	Lower resolution Variable magnification Potential distortion caused by positioning errors	Low
Tomography	Cross-sectional imaging of the implant site	Yes	Visualization of anatomic information in the third dimension. Minimal superimposition Imaging limited to designated sites.	Limited availability. Moderate cost Technique sensitive Large learning curve	Moderate low, depending upon the number of sites
Computed tomography	Cross-sectional imaging of multiple implant sites	Yes	Easy visualization and interpretation. Accurate assessment of bone dimensions and density. Compatible with electronic implant placement software	Imaging of entire oral cavity, not just sites of interest. Limited availability High cost	High
Magnetic resonance imaging	Cross-sectional imaging of multiple sites	Yes	Nonionizing radiation Adequate assessment of bone dimensions Allows assessment of healing in sinus lift procedures	Initial learning curve Appearance of tissues initially will be confusing for clinicians Cannot be used in patients with cardiac pacemaker, shrapnel wounds especially round orbits, retained ferromagnetic clips Limited availability Expensive	None

Table 2.3: Comparison of various dental imaging modalities

	Paralleling technique (IOPA)	*Lateral cephalogram*	*OPG*	*Complex motion tomography*	*Computed tomography (MSCT)*
Distance Measurements					
Mesiodistal accuracy	<1.0 mm	NA	Unreliable	Unreliable	<0.5 mm
Bone height accuracy	<1.0 mm	Midline only	Unreliable	Unreliable	<1.0 mm
Bone width accuracy	NA	Midline only	NA	<1.0 mm	<0.5 mm
Bone Quality Assessment					
Cortical plate thickness	NA	NA	NA	<1.0 mm	<0.5 mm
Cortical plate density	Qualitative	Unreliable	Unreliable	Qualitative	<0.5 %
Trabecular density	Qualitative	Unreliable	Unreliable	Qualitative	<0.5%
General Overview					
Anatomy and pathology	Local only	Good	Good	Good	Very good
Identification of possible implant sites	Local only	Unreliable	Good	Good	Very good

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Chapter 3

History of Dental CT

Sushma P Jaju

Tomography had been one of the pillars of radiologic diagnostics until the 1970s when the availability of minicomputers and of transverse axial scanning method (due to the work of Godfrey Hounsfield and Allan McLeod Cormack) gradually supplanted it as the modality of CT. The first commercially viable CT scanner was invented by Sir Godfrey Hounsfield in Hayes, United Kingdom at EMI Central Research Laboratories using X-rays. Hounsefield conceived his idea in 1967 and it was publicly announced in 1972. Allan McLeod Cormack of Tufts University in Massachusetts independently invented a similar process, and both Hounsfield and Cormack shared the 1979 Nobel Prize.

Computerized tomography scanners were initially called computerized axial tomography (CAT) scanners because they were designed to produce images in the axial plane. Direct coronal CT images were first produced in the late 1970s. The first CT scanner developed by Hounsfield in his laboratory at EMI required several hours to acquire the data for a single slice, and took several days to reconstruct the corresponding image. Data acquisition and image reconstruction became progressively faster during the 1970s and 1980s, although the speed of the scanners remained limited by the need for "stop-start" slice-by-slice acquisition. That is, in conventional CT, an axial slice is generated by rotating an X-ray tube and detector array in a 360° circle around the patient. After a 360° rotation, the rotating gantry reverses direction to prevent disruption of the tethered cables that transfer the data from the detector array to the computer. Such sequential slice acquisition limits the speed of conventional CT, prevents volumetric data acquisition, results in slice misregistration, and limits temporal resolution so that multi-phase volumetric scanning is not possible. Dental patients were first evaluated using coronal scans but it had numerous limitations. It was very difficult to obtain scans truly perpendicular to the alveolar ridge. Scanners had limited ability to tilt, and elderly patients cannot bend their necks very much. Hence the images obtained were not truly coronal. The measurements of the alveolar ridge was hence overstated. Also dental restorations produced streak artefacts. Hence, direct coronal scanning for evaluation of implants sites was never accepted by implantologist. Reformatted sagittal and coronal spinal CT became standard in the early 1980s. The development of spiral (or helical) CT in the late 1980s represented a technologic breakthrough. In spiral CT, data is carried from the rotating gantry to the computer by slip rings, which allow continuous gantry rotation and data transfer. Scanning can be performed while the patient is moved slowly but continuously through the gantry. The ability to continuously scan allows for "non-stop" volumetric data acquisition. Data is gathered on a three-dimensional volume in a spiral fashion. Images are reconstructed from the data volume. Prior to this development, the first useful technique for pre-implant imaging of jaw anatomy was conventional orthoradial tomography, using a complex (circular, spiral, or hypocycloidal) blurring device, such as the Scanora or CommCat (Soredex, Marietta, Ga.; Imaging Sciences International, Roebling, NJ). Reformation is a technique whereby the digital data that make up the axial cross-sectional images produced by the CT scanner are rearranged so that they are displayed in alternate planes. In the early 1987, Melvin Schwarz, an experienced periodontist, completed his training in Branemark implants from Sweden. He was concerned about the lack of preoperative determination of the exact position for optimal implant placement. He collabora-

ted with Stephen Rothman, a neuro-radiologist from California for studying the role of CT in implant site assessment. Stephen Rothman was a Medical Director of Multiplanar Diagnostic Imaging Co. He combined a clinical CT scanning practice and a computer science group, led by Michael Rhodes, consisting of three PhDs in computer science and engineering and nine programmers. They had previously designed a state-of-the-art computer software for reformatting CT images of spine into precisely sized sagittal and curved coronal images.

Rhodes and his associates designed a dentist-friendly program and patented the first dental reformation package, called dentascan. This software was unique in the sense, that it is only radiologic procedure specifically designed and produced to solve a specific clinical problem for a single surgical procedure. In 1993, Sim/Plant for Windows was developed, allowing clinicians to utilize their own computers to plan an implant case interactively. The further benefits of the Sim/Plant program are the availability to measure bone density, measure accurately the distance to vital structures, mark clearly vital structures such as the inferior alveolar nerve and sinus, and measure the volume needed for a sinus graft. The ability to see implants from a 3-D perspective, allowing verification of parallelism, is advantageous with respect to reducing offset loading of implants.

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Chapter 4

Working of Dental CT

Prashant P Jaju

Since its clinical introduction in 1991, volumetric CT scanning using spiral or helical scanners has resulted in a revolution for diagnostic imaging. Helical CT has improved over the years with faster gantry rotation, more powerful X-ray tubes, and improved interpolation algorithms. However, in practice the spiral data sets from monoslice systems suffered from a considerable mismatch between the transverse (in plane) and the longitudinal (axial) spatial resolution. This advancement has resulted in introduction of multislice CT (MSCT) scanners. Currently capable of acquiring four channels of helical data simultaneously, MSCT scanners have achieved the greatest incremental gain in scan speed since the development of helical CT and have profound implications for clinical CT scanning. Fundamental advantages of MSCT include substantially shorter acquisition times, retrospective creation of thinner or thicker sections from the same raw data, and improved three-dimensional rendering with diminished helical artefacts.

Dentascan is a special post-processing software used in these multislice CT. Various companies are producing this software under different generic names **(Table 4.1)**.

Table 4.1: Different companies and dental CT software name

Software	*Company*
Dentascan (1987)	General electric
Image master 101 (1988)	General electric
Sim/plant (1993)	Columbia scientific
Syngo dental CT	Seimens

PROCEDURE OF SCANNING

During the procedure, the patient is placed supine in the gantry, using a head holder, chin strap, and sponges on either side of the head to prevent motion **(Figs 4.1 to 4.3)**. The patient head is oriented in the center of the scan field with the use of lateral laser light marker for positioning. The patient position in 'head-holder' is such that the hard palate is nearly parallel to gantry beam as acquisition is taken without angulations.

The patient is then instructed not to make chewing or swallowing maneuvers. Patient information is entered into the registration form available on the computer **(Figs 4.4 and 4.5)**. A lateral digital scout view (Scan projection radiograph/alignment image/localizer) is then obtained to define the upper and lower limits of the study and to determine if the scan plane is parallel to the alveolar ridge **(Fig. 4.6)**.

In case of upper jaw angulation is along hard palate and in lower jaw it is along inferior border of mandible

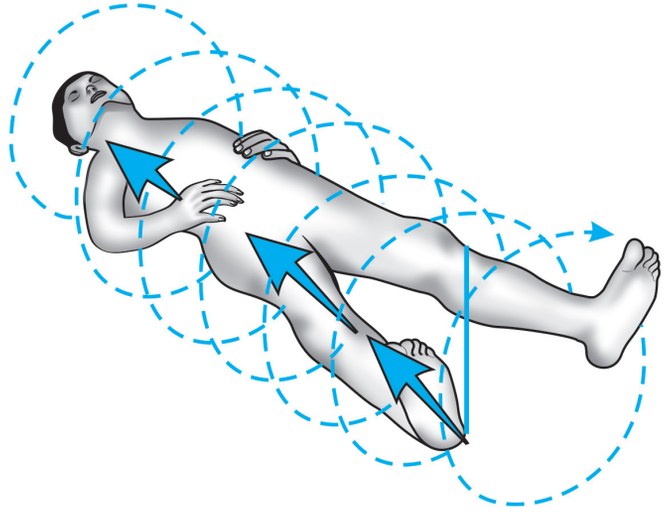


Fig. 4.1 Mechanism of action of spiral CT scan

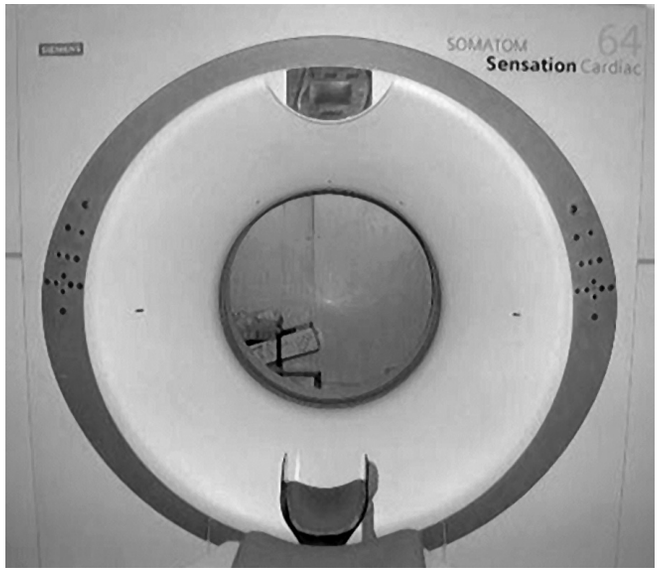


Fig. 4.2 CT scan gantry with head rest

Fig. 4.3 Patient positioning in the gantry

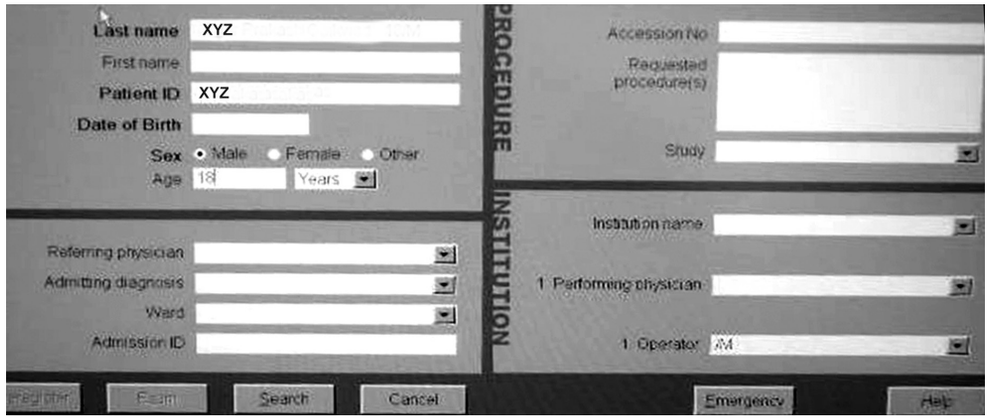


Fig. 4.4 Patient registration template

or the mandibular occlusal plane **(Figs 4.7 and 4.8)**. Once the scan plane is corrected, 0.6×64 mm contiguous scans are obtained using a bone algorithm, 512×512 matrix, 120 kV and 90 mAs. If both the mandible and maxilla are studied, a separate run is performed because the scan angle of the mandible is different than that for maxilla.

Scan direction is caudocranial beginning with the mandible base and extends to include the alveolar crest for the mandible, whereas for the maxilla the scan plane starts with the alveolar crest and extends upward to include all root tips. Axial images are acquired and then these images are processed with the dental CT reformatting program.

Choosing the Scanning Plane (Table 4.2)

Selection of scanning plane depends upon:

1. Oral cavity anatomy
2. Metallic restorations in oral cavity
3. Proposed site of dental implant
4. Proposed angulation of dental implant.

It is the responsibility of the referring implantologist to specify the scanning plane.

In MSCT scanner, the patient should be positioned so that the scanning plane is vertical while in CBCT scanner it should be horizontal. Proper selection of scanning plane reduces metal artefacts. It is always better to scan parallel to metal to minimize the artefact error.

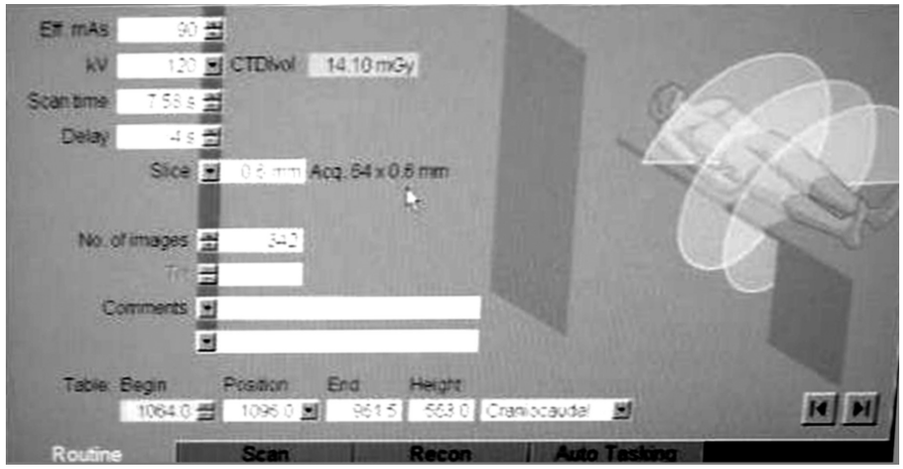


Fig. 4.5 Parameters adjustment

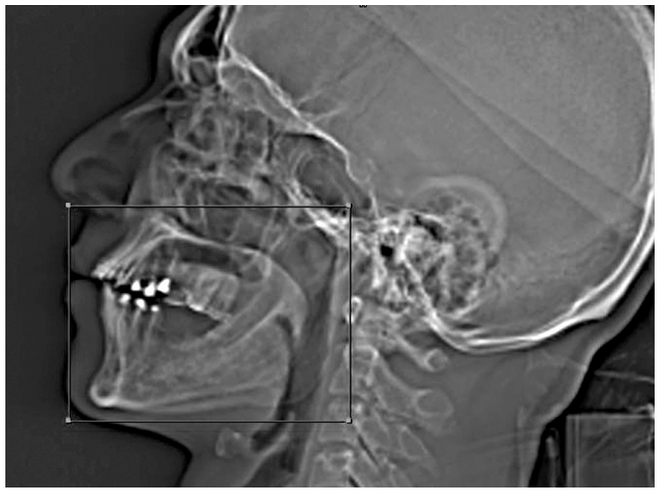


Fig. 4.6 Selection of scan area

Fig. 4.7 Marking points on the center of ridge

Loading the Images

After loading the images into the dental task card, and defining the panoramic line, the following layout is displayed:

- *Segment 1:* Shows a lateral MIP image of the jaw for overview purposes, with a red reference line indicating the image plane displayed in the upper right segment **(Fig. 4.7)**.
- *Segment 2:* Contains all axial MPR reference images in an image stack and shows the drawn panoramic reference line and the starting and end point of later reconstructions indicated with S (Start) and E (End) **(Fig. 4.8)**.
- *Segment 3:* Shows paraxial slice lines.

Fig. 4.8 Scan plane placed parallel to inferior border of mandible

❖ *Segment 4:* Shows up to seven panoramic lines **(Fig. 4.9)**.

An axial image that nicely shows the curve of the mandible or maxilla at the level of the roots of the teeth is selected by the radiologist and a curved line, along the midportion of the alveolus, is superimposed on the axial image by depositing the cursor on several different points along the curve of the jaw.

The program then automatically connects these points to produce a smooth curve that is superimposed on the jaw.

Preparing the Reconstruction of Dental Images

Defining a Panoramic Line

As described above, the base points are marked and double click onto the last base point.

The MPR from segment 2 is duplicated in segment 3 and 4.

Editing the Panoramic Line

In case of unsatisfactory panoramic reference line, it can completely deleted and a new line is drawn.

Table 4.2: Choosing the scanning plane

Type of image	*Indication*	*Advantages*	*Disadvantages*
Axial slices parallel to occlusal plane	Maxilla, mandible or both	Minimal metallic artefact Cross-sectional images are appropriate for planning implants vertical to the occlusal plane	NA
Axial slices parallel to lower border of mandible	Mandible only	Minimal number of slices required to cover the mandible Cross-sectional images are appropriate for planning implants vertical to lower border	Images compromised by metallic restorations Position may be uncomfortable for the patient
Axial slices parallel to hard palate	Maxilla	Minimal number of slices required to cover the sinuses Cross-sectional images are appropriate for planning implants vertical to the maxillary ridge	Images may be compromised by metal artefacts

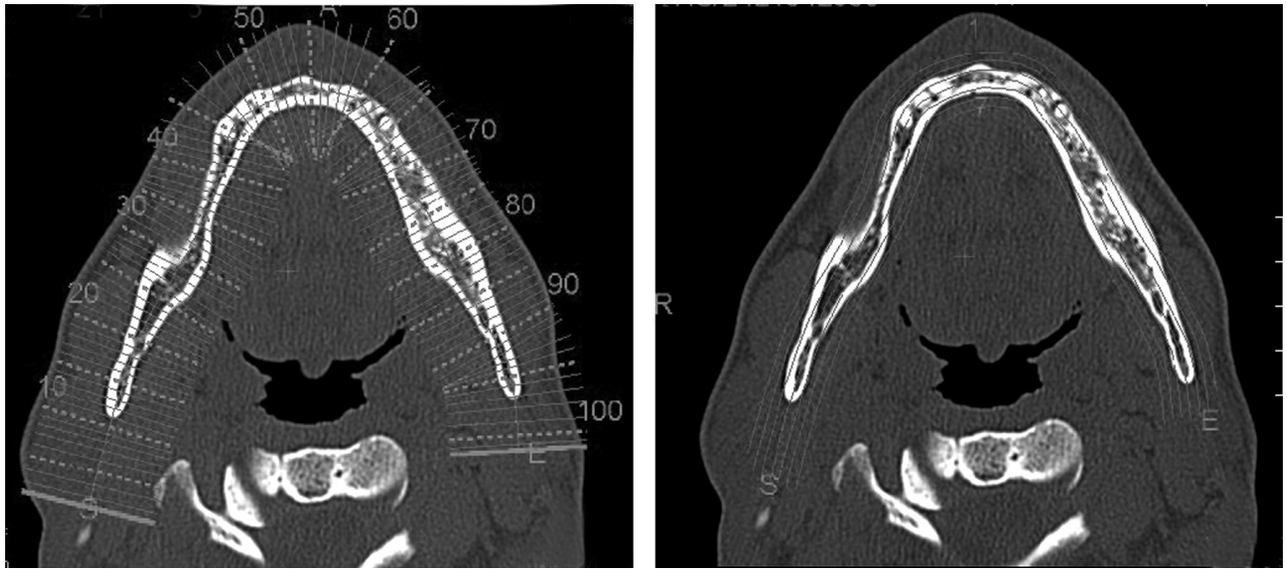


Fig. 4.9 Perpendicular (Paraxial) and parallel (Panoramic) cuts

Panoramic View Parameters

The panoramic view parameters are then defined from panorama option in the task bar.

- **Number of views:** Number of views obtained are seven **(Fig. 4.10)**.
- **Distance in mm:** The distance between the panoramic views is 1 mm.
- **Thickness in mm:** Slice thickness of 1 mm.

The curved line defines the plane and location of the reformatted panoramic images.

Several images can then be reformatted both buccally and lingually to this curve.

Paraxial Slice Parameters

Then reconstruction parameters for paraxial slices in the paraxial task card is conducted.

- **Length in mm:** Defines the length of the reconstructed paraxial slices. It is 30 mm.
- **Distance in mm:** Defines the distance between the paraxial slices. It is 2 mm.

Then the orthogonal checkbox is selected so that the paraxial slices are reconstructed orthogonal to the reference image. When the program is completed, three types of images are displayed, axial, cross-sectional, and panoramic.

Filming

Images are transferred on films, and this data is set to actual scale without magnification **(Fig. 4.11)**. These data sets are also available to be viewed on any PC as these data are burned on CD with DICOM reader. Ticks marks are appended to each image to facilitate localization of visualized anatomic structures. The distance between each tick mark is equal to the amount that the scanner table moved between each slice. Generally the total distance is of 10 cm. If proper filming technique is used and the camera is carefully maintained, life sized images are obtained. To ensure the most precise determination of the magnification factor, the distance between 100 tick marks should be periodically be measured. It should measure 10.0 cm. If the marks are less than 100.00 mm, any measurement made will be underestimated. If this distance is less than 4 mm, the scan should be considered as if it were life sized because this small error can provide the safety margin for the surgeon. If the measured distance is significantly greater than the expected 100.0 mm, the magnification factor is calculated by dividing 1.0 by the amount of the actual measurement. Measurements made directly from the film are corrected by multiplying the measured distance by the magnification factor.

Regarding the Software

The images are transferred on CD with a DICOM viewer. This allows the dentist to study the scan and select the appropriate the implant site. Various options are available on the compact disk. These options are as follows **(Flow chart 4.1)**:

1. Topogram
2. Axial images
3. Patient protocol
4. MIP
5. Reference plane
6. Paraxial images
7. Panoramic images.

Topogram

The topogram shows position of the patient in the gantry **(Fig. 4.12)**.

Axial Images

This section present CT axial images taken with scanning starting from caudocranially. It includes the maxilla along with the alveolar process and followed by mandible with its alveolar process. This view gives a topographic view of the jaws and at the root level of the alveolar process the reformatting is done to provide panoramic and paraxial images **(Fig. 4.13)**.

Patient Protocol

The patient protocol defines basic information about the dental scan. It includes the patient's name along with age, sex. Also radiologist name and the date and time of scan is displayed. It also shows total milliampere seconds; kilovoltage, DLP, TI, cSL.

MIP

It shows the reference plane used for scanning procedure. For maxillary scan, the plane is kept parallel to the hard palate and for mandible it is kept parallel to the occlusal plane or the inferior border of mandible.

Reference Plane

An axial image that nicely shows the curve of the mandible or maxilla at the level of the roots of the

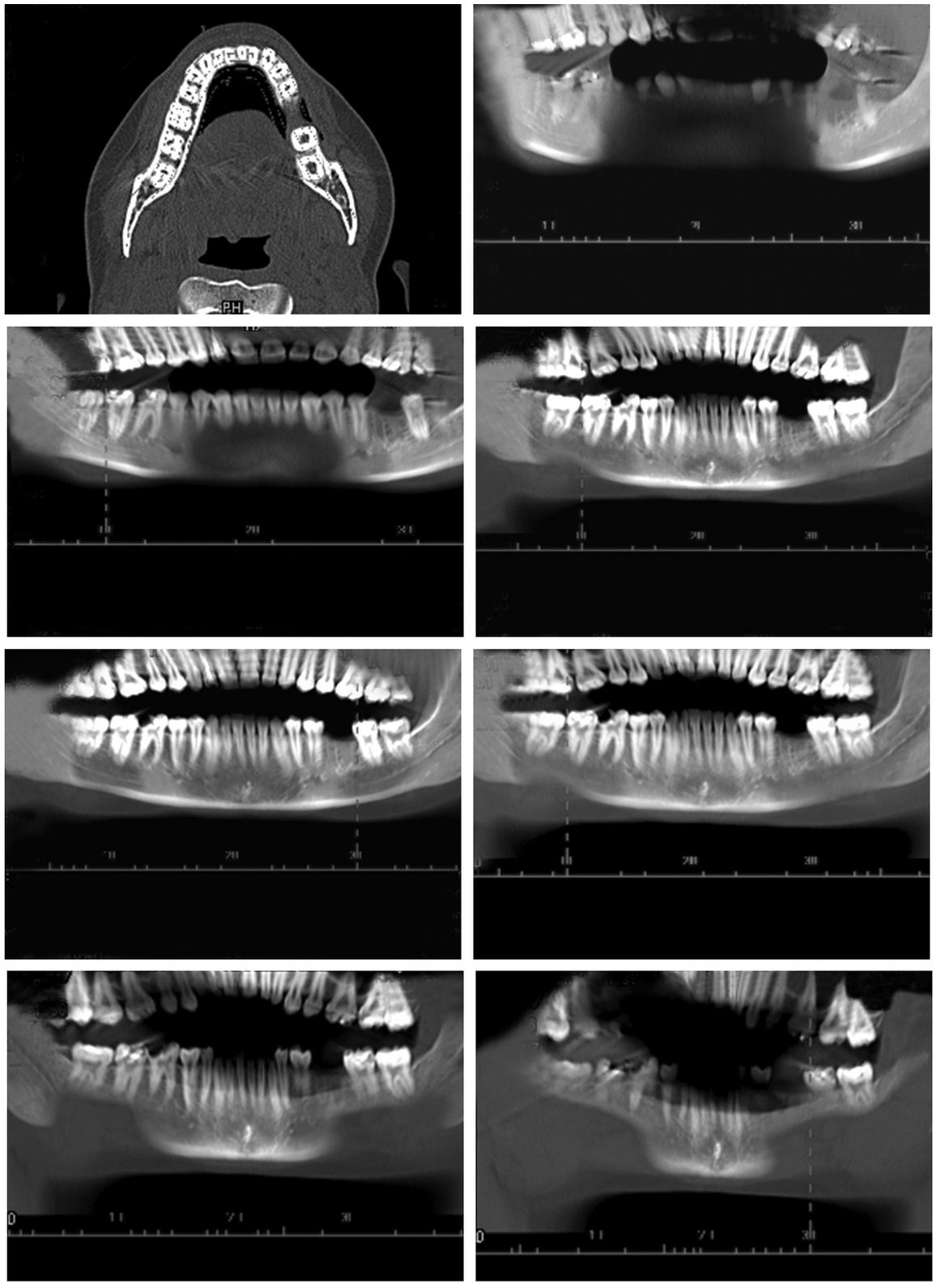
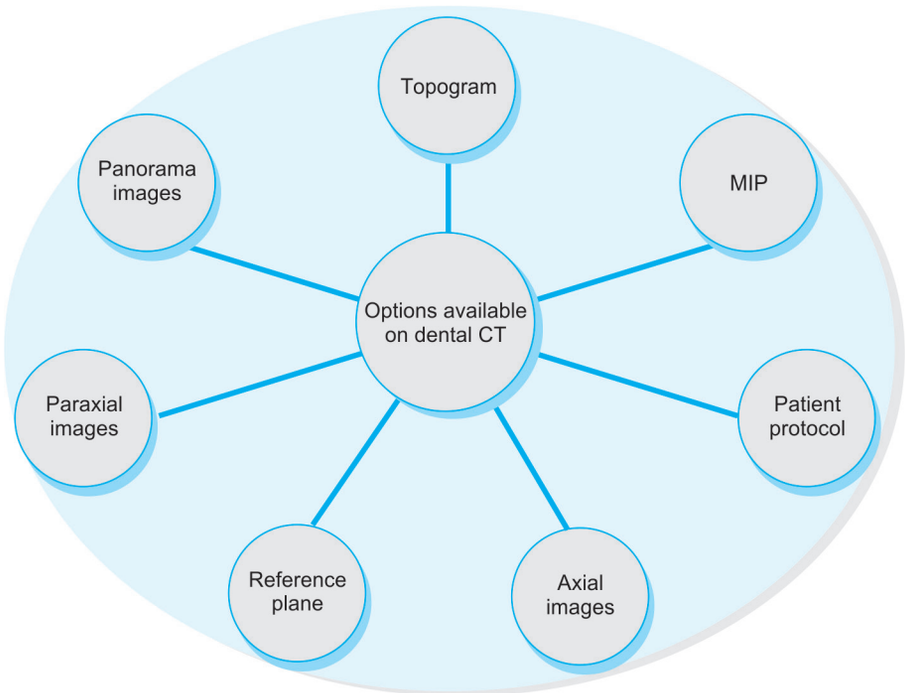


Fig. 4.10 Panoramic images from buccal to lingual side

Fig. 4.11 Processing unit

Fig. 4.12 Topogram

Flow chart 4.1 Option available on dental CT



teeth is selected by the radiologist and a curved line, along the midportion of the alveolus, is superimposed on the axial image by depositing the cursor on several different points along the curve of the jaw. The program then automatically connects these points to produce a smooth curve that is superimposed on the jaw.

Reference points are marked along the ridge beginning from the right side extending towards the left side. This is marked as S (start) and E (end). Then perpendicular lines are created which gives the paraxial images while lines along the arch give the panoramic images **(Fig. 4.14)**.

Paraxial Images

The paraxial images are images are present in this section. This section begins with multiple numbered lines that the program automatically creates perpendicular to the curve. It begins from the right side of the image. This image provides information about the height and width of the alveolar ridge in the buccolingual plane. The number of images varies with various parameters like the beginning of the starting point, slice thickness selected. Thicker slice gives fewer images. Along the left side of the screen information regarding the patient is present. It also presents with tools 1 and 2 and the layout **(Fig. 4.15)**.

Tool 1

1. *First option is magnifying glass:* Utilization of this tool provides a magnified view of the image.
2. *Second option is zoom:* Utilization of this tool provides to zoom the required image according to the operator satisfaction. But resolution seems to be lost with zoom tool.
3. *Third option is of undo:* It reverses all the changes made in the image.
4. *Fourth option is of linear scale:* This scale is useful in measuring the width and height of the ridge in centimeters.
5. *Fifth option is angular measurement:* This option provides angular measurement providing information regarding angle at which implant can be placed. This option can be used in post-implant cases to verify the angle of implant placement.
6. *Sixth option is pixel lens:* This option gives subjective value of the density of the cancellous and cortical bone.
7. *Seventh option is reversal of images:* This tool reverses the image, i.e. right image is displayed on left side and vice versa.
8. *Eight option is rotation of the images:* This option rotates images along the quadrant.
9. *Ninth option is inversion of grayscale:* This tool inverses the grayscale of the images. This option provides a soft tissue window.
10. *Tenth option is movie tool:* Utilization of this tool requires the operator to be in the CT scan center. It cannot be utilized by the dentist on his/her personal computer.
11. *Eleventh option is making report:* This also requires the operator to be in the CT scan center. It cannot be utilized by the dentist on his/her personal computer **(Fig. 4.16)**.

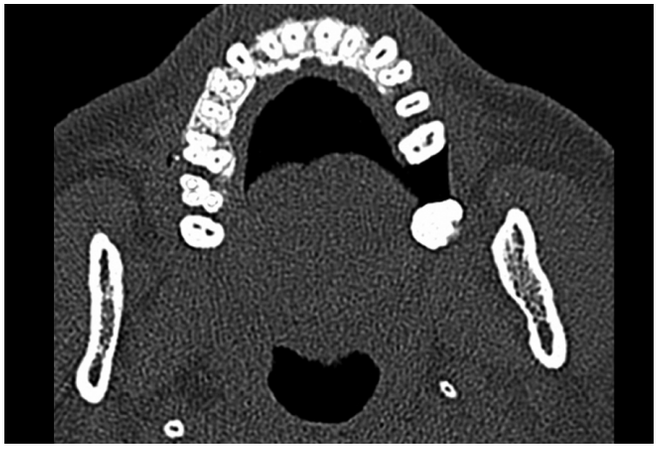


Fig. 4.13 Axial image

Tool 2

1. *First option is drawing of annotation:* This option provides four tools like circle, rectangle, arrow

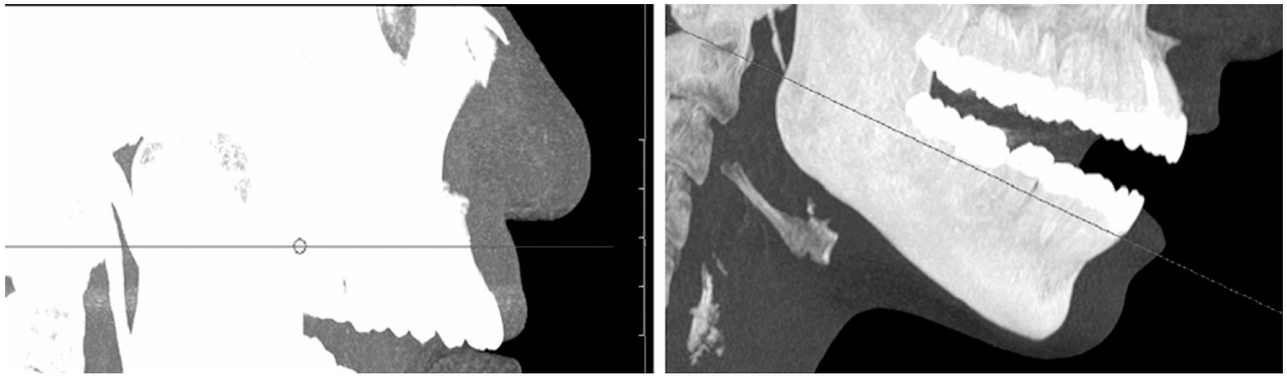


Fig. 4.14 Reference plane for maxilla and mandible

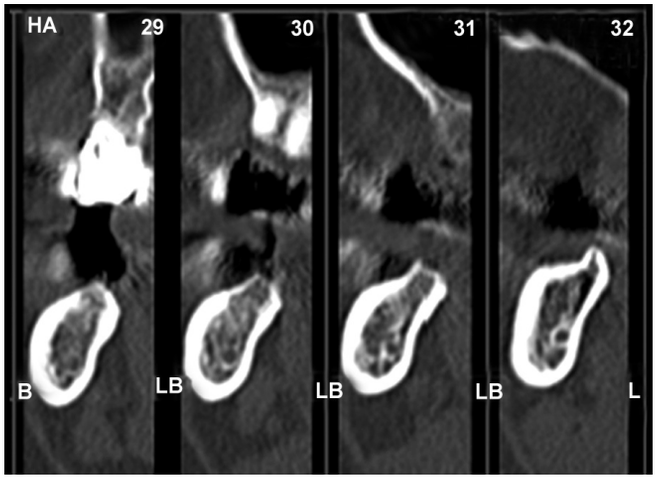


Fig. 4.15 Paraxial images

and free hand. Circle can be drawn on the images of proposed implant sites. With right click circle statistic can be displayed which gives a minimum and maximal pixel value along with standard deviation. Rectangle formation zooms a selected area. Free hand helps in drawing free hand on the images. Arrow can be used to mark particular landmark present on the images.

2. *Second option is text annotation:* This option provides writing of text on the images such as height and width of the proposed implant site.
3. *Third option is copying images:* This option copies the images to the clipboard for future use.
4. *Fourth option is printing of images:* This tool cannot be used on the personal computer.
5. *Fifth option hides the image text:* This option hides the basic information about the scan and patient's personal details present on the image. These images can be saved and utilized for future use.
6. *Sixth option is edge enhancement:* This option enhances the edge of the image. This is displayed in form of kernel **(Fig. 4.17)**.

Layout

This option provides presentation of the images either in form of single image or 1×1, 1×2, 2×2, 3×3, 4×4 layouts according to the wish of the operator **(Fig. 4.18)**.

Panoramic Images

Panoramic images present with seven panoramic sections extending from the buccal side towards the lingual side.

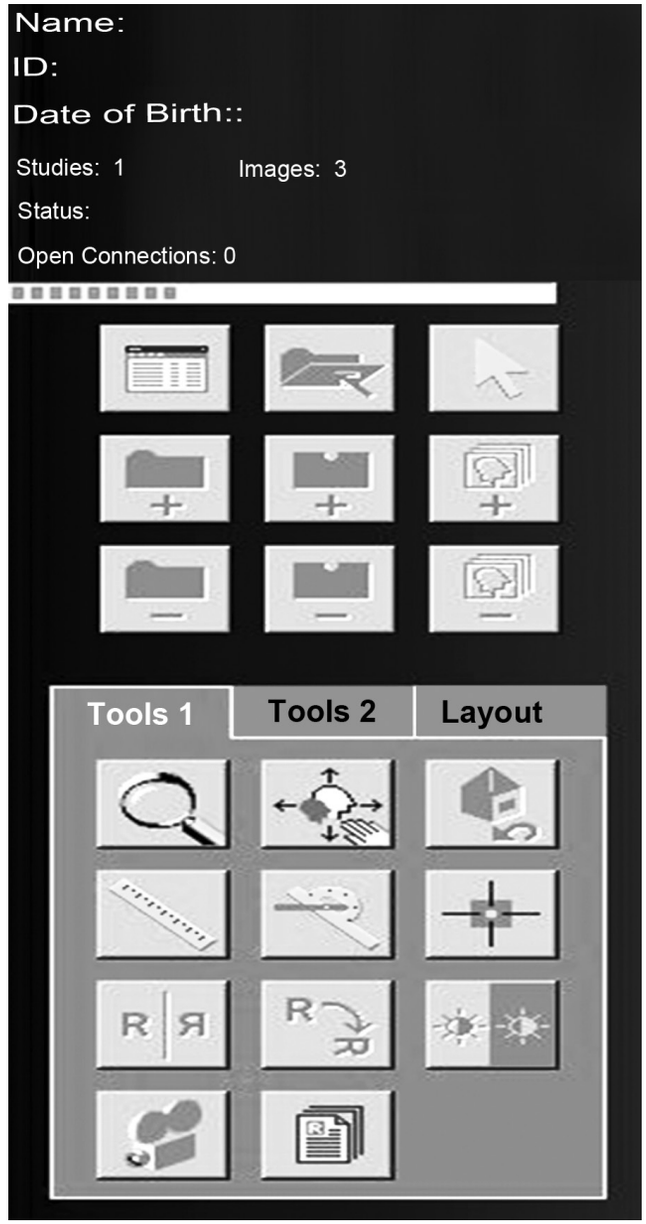


Fig. 4.16 Tool1 layout in dental CT software

Middle section generally number 4th slice gives the most adequate information about the jaw. Numbering is provided at the base of the image which is similar to those present on the paraxial images. This view can be used to visualize the teeth arrangement and it can also be used to locate the inferior alveolar canal which cannot be appreciated on the paraxial slices and also provide with a very good overview of the general situation, since the panoramic cuts resemble conventional panoramic radiographs, which are familiar to dentists.

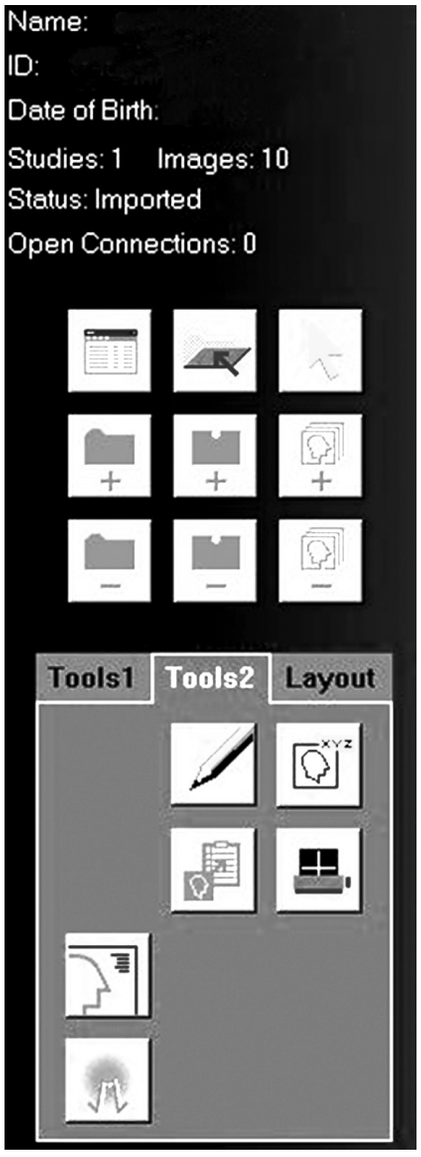


Fig. 4.17 Tool 2 layout in dental software

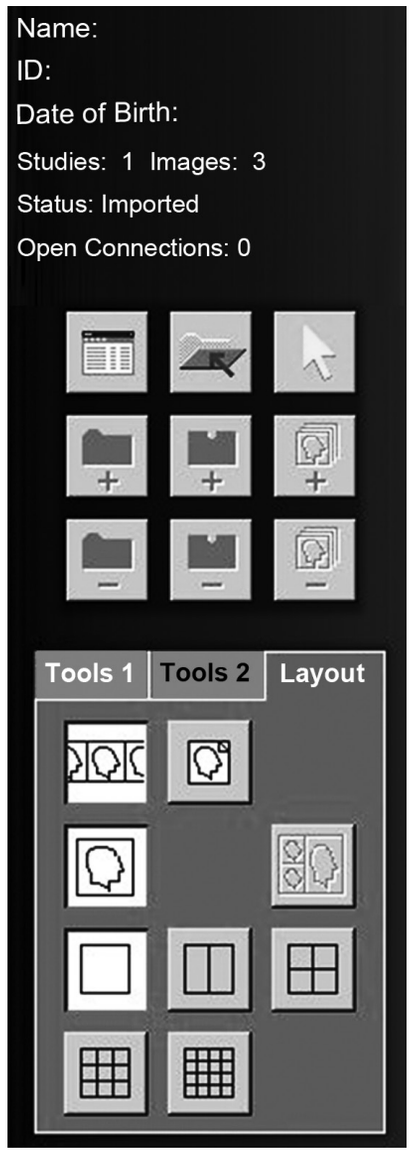


Fig. 4.18 Layout structure in dental CT software

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Chapter 5

Anatomical Landmarks as on Dental CT

Prashant P Jaju

All the maxillofacial landmarks can be clearly demonstrated in a three-dimensional view on dental CT **(Table 5.1)**.

Table 5.1: Important landmarks seen on dental CT

Maxilla	*Mandible*
Nasopalatine foramen/incisive foramen	Genial tubercles
Nasal cavity	Diagastric fossa
Maxillary sinus	Lingual vascular canal
Greater palatine foramen	Mental foramen
Pterygoid plates	Mandibular canal
	Mandibular foramen

MAXILLARY LANDMARKS

Nasopalatine Foramen/Incisive Foramen

The incisive foramen (also called the nasopalatine foramen) in the maxilla is the oral terminus of the nasopalatine canal. It transmits the nasopalatine vessels and nerves which may participate in the innervations of the maxillary central incisors and lies in the midline of the palate behind the central incisors at approximately the junction of the median palatine and incisive sutures. On a periapical radiograph it appears as a round to oval radiolucency between the roots and in the region of the middle and apical thirds of the central incisors **(Fig. 5.1)**. The radiographic appearance varies depending upon the anatomical variations and also technique variation. On the dental CT nasopalatine canal can be visualized accurately. Course of nasopalatine canal cannot be seen on panoramic view but it can be visualized on paraxial slices **(Fig. 5.2)**. Hence the palatal orientation of the anterior maxillary implant can be planned.

Fig. 5.1 Incisive fossa seen on IOPA film

Identification of this landmark is crucial in cases of maxillary anterior implants as damage neurovascular bundle can lead to numbness and paresthesia.

Nasal Cavity

Nasal cavity (nasal fossa) are air filled cavities, appearing as a radiolucent shadow on the periapical radiograph of maxillary central incisors. In cases of placement of maxillary anterior implant, the identification of this anatomical structure is important to prevent postoperative

complications. Dental CT allows accurate measurement of the ridge height from the crest of the ridge to the floor of nasal cavity. Ideally implant length should be 2 mm away from the anatomical structure. Nasal cavity appears as a radiolucent shadow, seen on consecutive sections of paraxial images thus assisting in identification of any pathologies of nasal cavity **(Fig. 5.3)**.

Maxillary Sinus

Maxillary sinus is a critical anatomical structure in the maxillary posterior region of the jaw. The maxillary sinus, like the other paranasal sinuses, is an air-containing cavity lined with mucous membrane. It develops by the invagination of mucous membrane from the nasal cavity. Being the largest of the paranasal sinuses, it normally occupies virtually the entire body of the maxilla. The sinus may be considered as a three-sided pyramid, with its base the medial wall adjacent to the nasal cavity and its apex extending laterally into the zygomatic process of the maxilla. The maxillary sinuses are often asymmetric. Like wise the anterior sinus borders are important in the anterior posterior implants, especially in cases of severe maxillary anterior ridge resorption. Dentascans provides images of the maxillary sinus in all dimensions. It is the modality of choice in the evaluation of diseases of nose and paranasal sinuses. Pathoses appear as mucosal thickening and diagnosed preoperatively, treatment can be provided prior to implant placement. Dentascan provides information regarding the cortical bone in the floor of the nasal cavity and maxillary sinuses prior to implant placement. Dentascans are expensive investigation but provides a three-dimensional information at an early stage with precise measurement and exclude patients not suitable for implants for technical reasons and thus save time and money both for the patient and the surgeon. Thus dentascans of the upper alveolar process justifies its place in the presurgical evaluation of the edentulous patient who is in need of implants **(Fig. 5.4)**.

Based upon the distance of the ridge from the floor of the maxillary sinus, treatment plan can be made as suggested by Carl Misch **(Table 5.2)**.

SA: Subantral **(Figs 5.5 and 5.6)**.

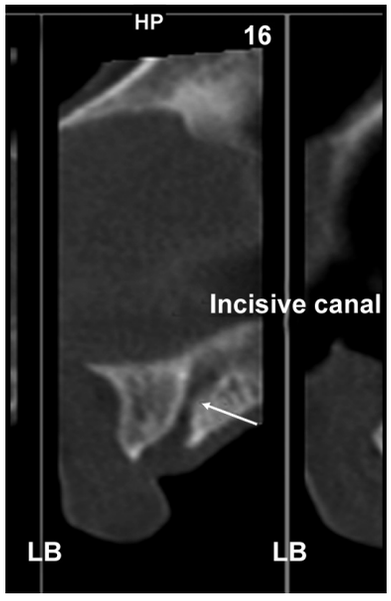


Fig. 5.2 Incisive canal on dental CT seen as narrow canal

Greater Palatine Foramen

Greater palatine foramen is present on the palatal surface of maxilla. Its position can be varying between the first

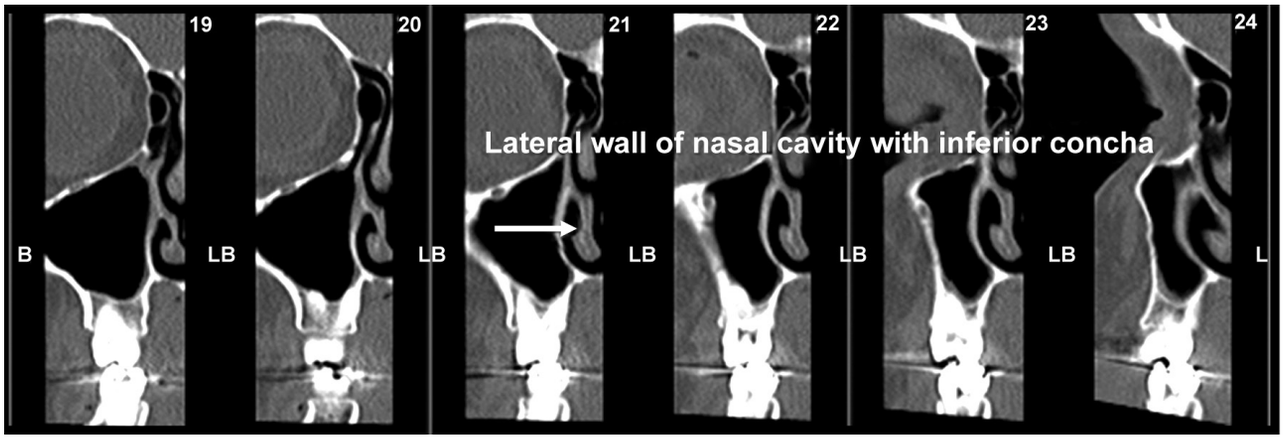


Fig. 5.3 Nasal cavity seen on dental CT with inferior concha

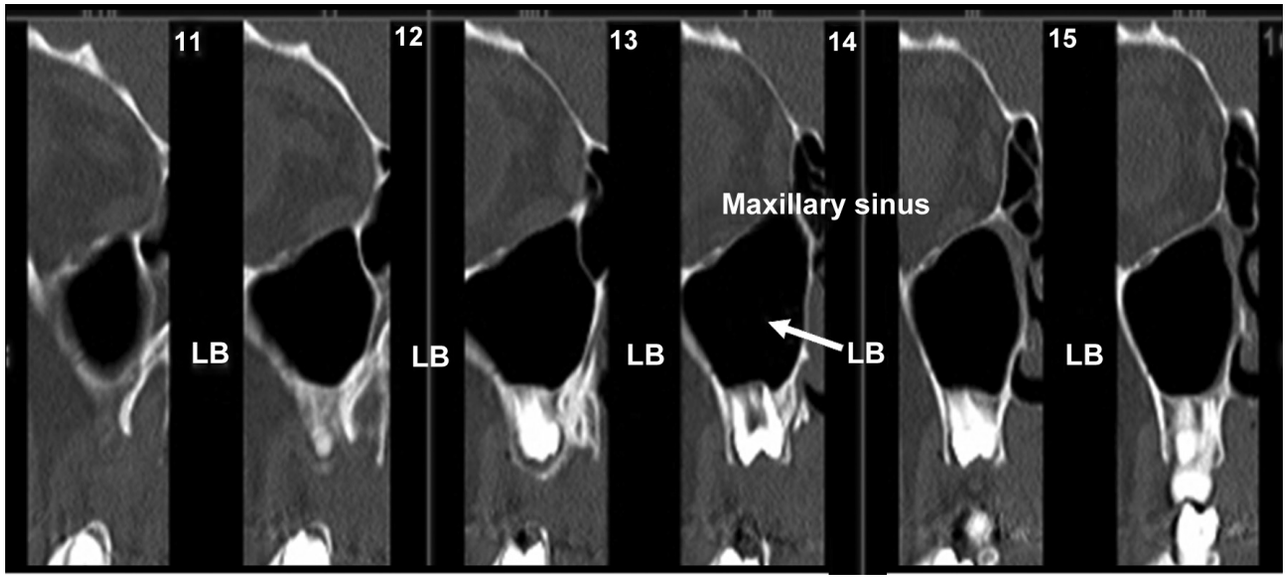
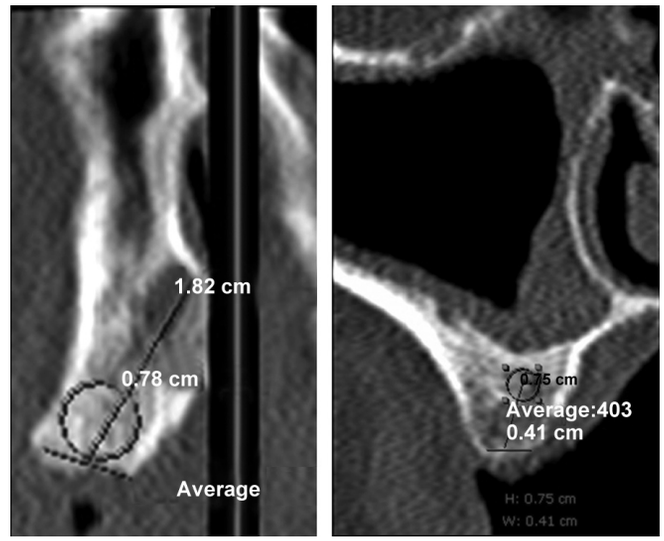


Fig. 5.4 Maxillary sinus on dental CT

Table 5.2: Height available at implant sites and proposed treatment plan

Groups	*Height available at the implant site (mm)*	*Treatment available*
SA 1	>12 mm	Conventional implant procedure
SA 2	10–12 mm	Sinus lift, division A root form
SA 3	5–10 mm	Lateral wall approach sinus graft and delayed division A root form
SA 4	<5 mm	Lateral wall approach sinus graft and delayed division A root form



SA 1 SA3

Fig. 5.5 Radiographic appearance of SA 1 and SA 3 on dental CT

and second maxillary molars. Identification of this landmark is critical in case of maxillary posterior implant. Damage to this foramen can lead to paresthesia **(Fig. 5.7)**.

MANDIBULAR LANDMARKS

Lingual Vascular Canal

Mandibular anterior region has long being considered as a safe zone for implant placement, with implant length extending up to the inferior border of mandible. But recent literature suggests serious life-threatening complications such as sublingual hematoma formation, upper airway obstruction and profuse bleeding. Thus, a proper anatomical, radiological and surgical considerations must be done prior to implant placement in interforaminal region of anterior mandible. A number of researchers have recommended that blood vessels and nerves could enter the lingual foramen. Ennis, Suzuki and Sakai, McDonnell et al. Darriba and Mendonca–Cardad and Givol et al. assumed a vascular content being an anastomosis of the sublingual branch of right and left lingual arteries. The artery could be of sufficient size to provoke a hemorrhage intraosseously or in the connective soft tissue, which might be difficult

Fig. 5.6 Axial, panoramic and paraxial images showing right maxillary sinus pathology

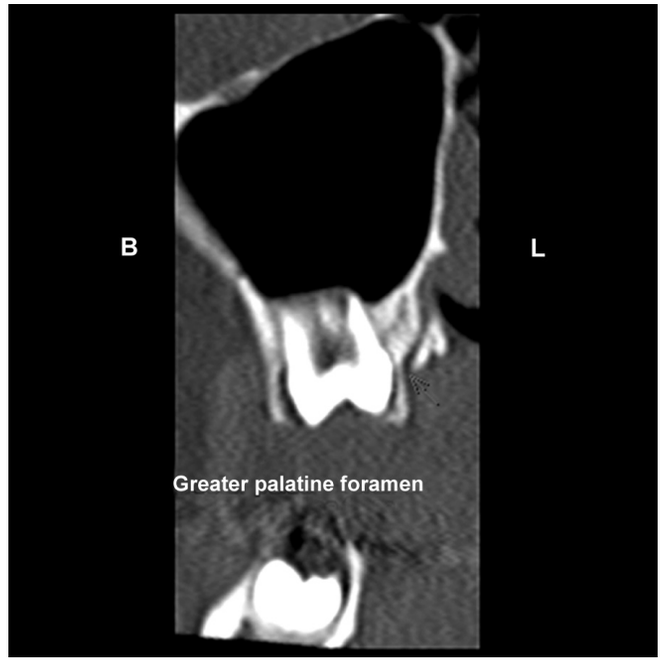


Fig. 5.7 Greater palatine foramen seen as a S-shaped canal

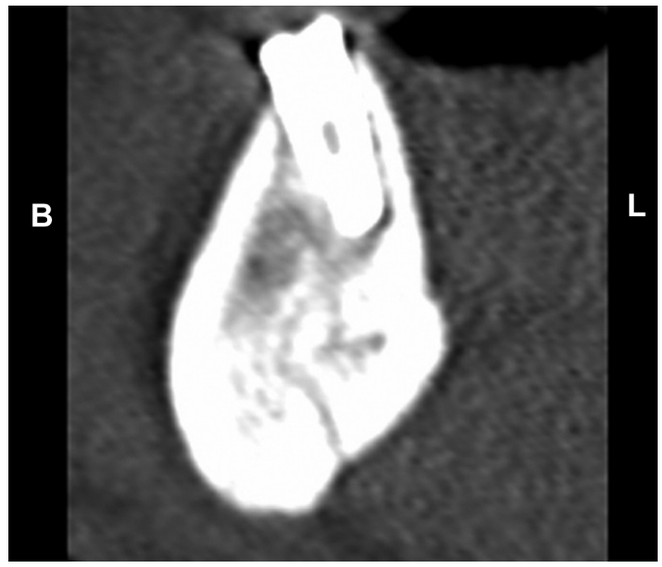


Fig. 5.8 Lingual vascular canal on dental CT

to control. Sutton described the structures associated with the foramen as a neurovascular bundle. Goaz and White stated that the foramen and canal were the termination of the incisive branch of the mandibular canal. According to Yoshida et al. found low frequency of occurrence (45.7%) of lingual foramen on internal surface of mandible on dry cadavers. According to McDonnell et al. lingual foramen was present in 99.04 percent in midline of mandible **(Fig. 5.8)**.

Yoshida et al. believed that lingual artery visualization on radiography was difficult and CT provides a adequate visualization of the vascular canal. Multiplanar reformation (MPR) provides excellent visualization of midline mandibular structure clearly depicting the lingual canal and size of the lingual canals correlate well with the results of anatomic studies. The small difference in the size values of the canals can probably be attributed to the fact that the smallest canals were

too small to be visible because of the limited resolution capability of CT.

Gultekin et al. in their study revealed typical lingual canal locations were the middle of the mandible and the premolar regions. Radiographic report of dental CT for pre-evaluation of implant sites should mention about the vascular channel present in mandibular anterior region before any surgical procedure is formulated. Dental CT offers the advantage of proper anatomic delineation of the jaw and depiction of the lingual vascular canals of the mandible, hence reducing the risk of implantation surgery in the preoperative phase **(Table 5.3)**.

Mandibular Canal

Inferior alveolar canal is the deterministic factor for implant placement in the mandibular posterior region. During treatment planning prior to mandibular implant surgery, it is important to determine the location of the mandibular canal. In the application of an implant system to the partially edentulous distal portion of the mandible, the inferior alveolar nerve is a vital anatomic structure that must be avoided. Positioning of implants close to the canal may result in vascular trauma or damage to the inferior alveolar nerve, resulting in paresthesia of the lower lip and mentalis muscle area. Also, bone healing around the dental implant may be impaired if the implant comes in contact with the soft tissues lining the inferior alveolar nerve and vessels. Routine radiographs provide information only about the distance of the inferior alveolar canal from the alveolar crest but are unable to delineate its buccolingual dimension. Canal may not be visible on conventional radiographic methods; it is probably related to the fact that the inferior alveolar neurovascular bundle is not always surrounded by an ossified canal. The bony sheath seems to disappear anteriorly toward the mental foramen. Similarly, in edentulous patients the diameter of the artery is smaller compared to dentate patients and hence the visibility of the canal may be affected. The mandibular nerve may course diagonally from a lingual location posterior to a buccal location in the area of the mental foramen. The buccal-lingual position of the nerve can only be seen in either axial or cross-sectional views of the mandibular ridges. Paraxial slices provide consecutive sections which depict the course of the inferior alveolar nerve up to mental foramen. Klinge et al. Lind et al. Todd et al. and Sonick et al. emphasized that mandibular canal is best demonstrated on dentascans **(Fig. 5.9)**.

The position of the mandibular canal may vary buccolingually such that implant placement is possible only to the buccal or lingual aspect of the canal **(Fig. 5.10)**.

Table 5.3: Literature study of complications of lingual vascular canal

Author	*Findings*
DuBrul (1980)	Sublingual artery running along the floor of the mouth can be of considerable size in the region of the molars and premolars and therefore is prone to substantial bleeding when injured.
Mason et al. (1990)	Several reports on major hemorrhage in the floor of the mouth caused by bleeding from different surgical procedures and implant placement in the mental region. They recommend that appreciation of the sublingual artery anatomy mandatory for those performing mandible implantation.
Boyes et al. (2002)	Extensive hematoma in the floor of the mouth, following implant placement in mandibular anterior region which rapidly became life-threatening, requiring an emergency tracheostomy to establish a surgical airway.
Kalpidis and Setayesh (2004)	Reported critical hemorrhagic episodes, related to dental implantation in the anterior segments of the mandible. To reduce the probability of such a grave complication, preventive and precautionary measures to be taken before, during, and after implant placement in the anterior mandible.
Issacson (2004)	Reported a case of sublingual hematoma in a 56-year-old man who underwent multiple mandibular tooth extractions and alveoloplasty and received endosseous implants.
DelCastillo et al. (2008)	Reported a case of sublingual hematoma in a 53-year-old man following a dental implant procedure, requiring admission to the hospital. The anatomy of the lower portion of the anterior mandibular zone, with the mylohyoid ridge, makes it particularly vulnerable to this kind of injury, particularly in patients with atrophic mandibles.
Pigadas et al. (2009)	It is vital to appreciate the shape of the lingual cortex and to select carefully the correct implant length and angulation.Imaging techniques that assess the mandibular anatomy in a sagittal plain such as lateral cephalometric radiographs and computed tomograms (CT) as well as surgical stents may be an advantage
Frenken et al. (2010)	A patient experienced severe bleeding in the floor of the mouth as a consequence of the placement of 2 implants in the resorbed anterior segment of the mandible. To reduce the probability of such complications knowledge of the local anatomy, good clinical inspection and various radiographic evaluations are important.

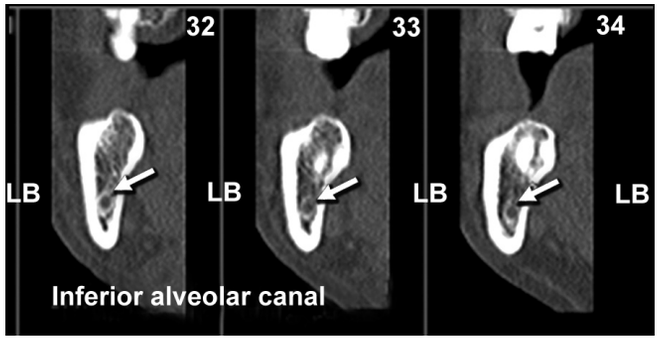


Fig. 5.9 Mandibular canal seen as oval to round radiolucency surrounded by radiopacity

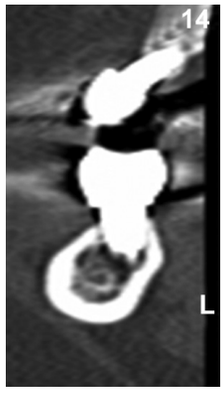


Fig. 5.10 Post implant placement on dental CT. Note implant placed superior and lingually to mandibular canal

The detection of mandibular canal is more difficult with increased slice thickness and slice interval with reduced tube current.

Visualization of the location of mandibular canal in posterior mandibular region is of paramount importance for implant placement. There are times when portions of the canal or even the entire canal may be difficult to visualize on the cross-sectional images. In this situation the following methods are helpful in locating the canal.

1. *Cortical niche sign:* Cortical niche sign refers to an indentation along the inner or medullary margin on the lingual cortex of the mandible. This niche is created by the mandibular nerve as it traverses the mandible. When present, it is a good way to identify the canal. Care should be taken not to confuse other cortical irregularities with the cortical niche sign. The cortical niche is a continuous defect seen on multiple cross-sectional images. When the canal is identified with the cortical niche sign, its location should be confirmed with the other methods **(Fig. 5.11).**

2. *Triangulation:* Triangulation utilizes the scale marks on the films to relate an anatomic structure well seen on one view to its location on another view. With this method, the panoramic and axial views can be utilized to identify the canal on the cross-sectional views.

3. *Position distance:* Finally, if a canal was identified in one of the cross-sectional images but not on others, the images on which it is identified were utilized to estimate

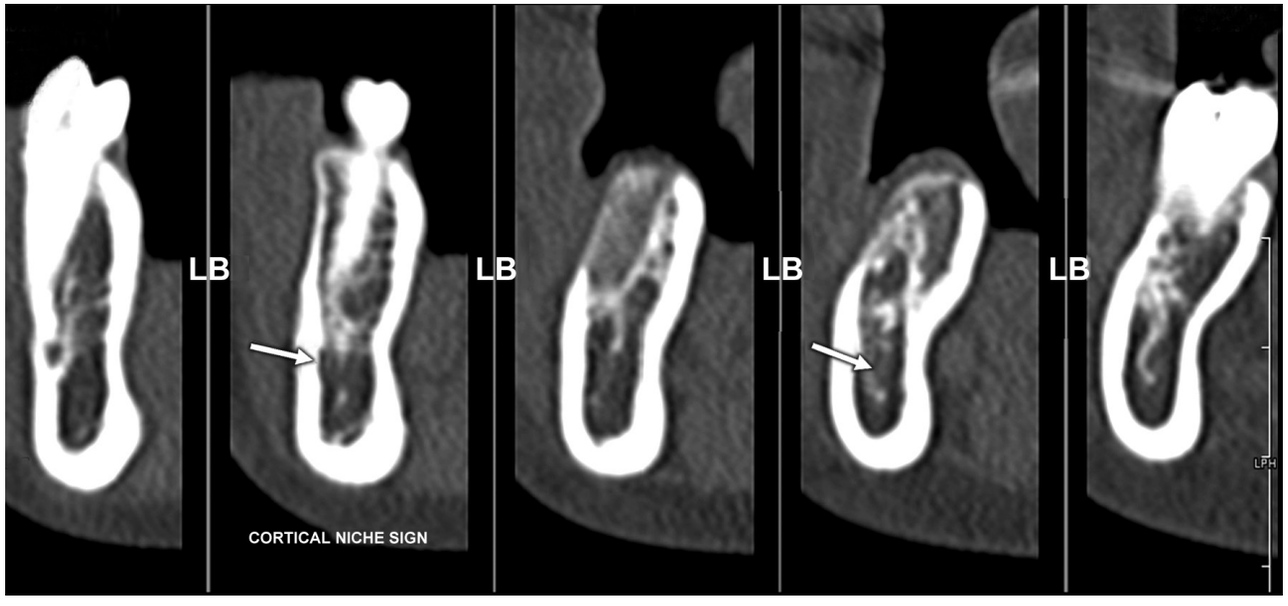


Fig. 5.11 Cortical niche sign as an indentation in successive images

the position of the canal on the other images. This could be done because the distance from the inferior border of the mandible to the bottom of the canal tend to be relatively constant. The only region where the distance was not constant was immediately adjacent to the mandibular foramen and mental foramen **(Fig. 5.12)**.

a. Panoramic view showing implant site on right mandibular first molar (Slice 40–42).
b. Lack of visibility of mandibular canal in paraxial images (Slice 40–42).
c. Contralateral site measurement giving a estimation of position of mandibular canal.

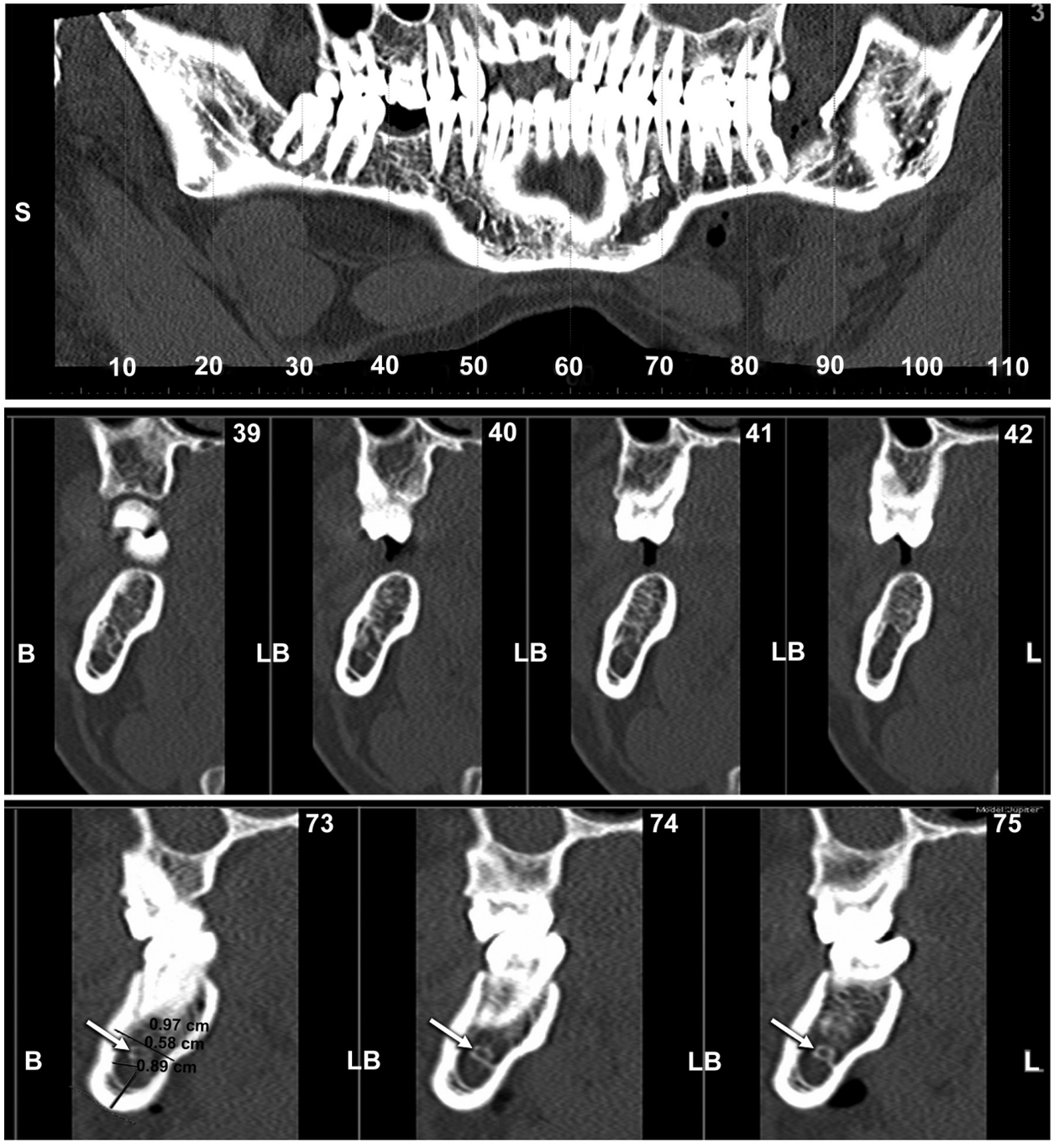


Fig. 5.12 Position distance rule

The mandibular nerve always extends more mesially than does the mental foramen. At its most anterior point, the nerve divides into the mental nerve, which curves back on itself and sweeps upward and toward its labial extent at the mental foramen. The terminal branch continues in one or more very small bony canals to provide sensory branches to the roots of anterior teeth. These bony canals can be identified on the CT scans. The anterior portion of the nerve forms a genu from inferior to superior. The length of the genu varies considerably. It is generally thought to extend approximately 3 mm forward of the mental foramen, but in some cases it extends up to 1 cm from the mental foramen. Recognition of this variation is important in the anteriorly edentulous patient. This can be appreciated on both the panoramic and paraxial images.

Mental Foramen

Dentascans is the radiographic method of choice to depict mental foramen **(Fig. 5.13)**. Variations in the position of the mental foramen are also common. Typically, the foramen is located halfway between the alveolar crest and the lower mandibular border between the first and second premolars. However, it may be found as far anterior as the canine and as far posterior as the first and second molars. The neurovascular bundle may loop downward, forward and medially before exiting from the foramen in a posterosuperior direction. In older edentulous individuals with resorbed ridges, the foramen may be near, or may actually emerge from, the alveolar crest

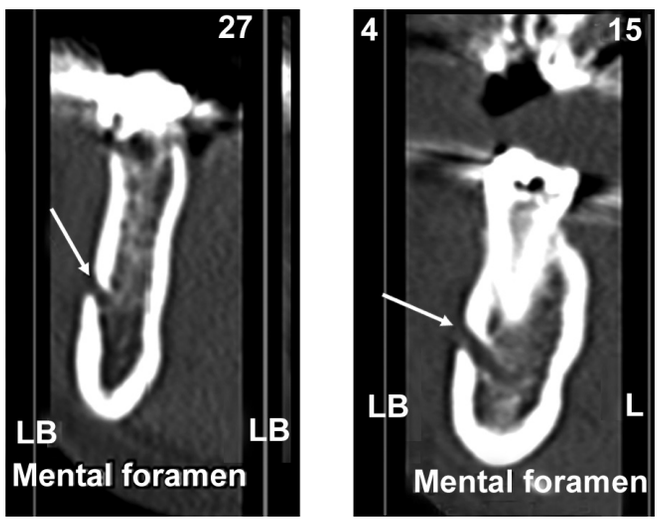


Fig. 5.13 Mental foramen as seen on paraxial image

Fig. 5.14 Anterior loop seen on conventional radiograph

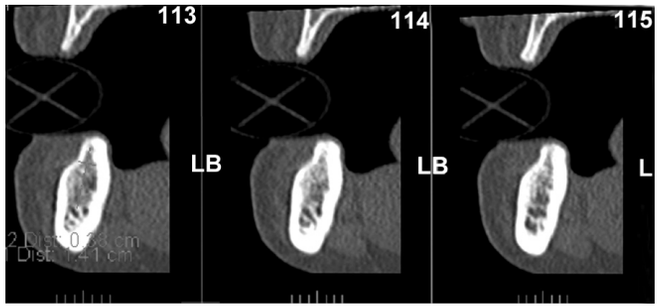


Fig. 5.15 Anterior loop seen on dental CT

likewise, CT detects the extent of any anterior looping prior to the nerve's exit from the mental foramen **(Figs 5.14 and 5.15)**.

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Chapter 6

Dental CT in Implantology

Prashant P Jaju, Prashant P Suvarna

"Forewarned is forearmed", is an old adage applied to the medical field and so is to the field of implant dentistry. Dental implants are gaining immense popularity and wide acceptance because they are the conservative method of replacing lost teeth, and restore function with proprioception, esthetics and thereby revamp the self-esteem of the patients.

The dental implant restorations have the highest survival rate compared with any other type of prosthesis to replace missing teeth. They do not decay or require endodontic treatment. They are also less prone to fracture and resist periodontal like disease better than teeth. Today, we see widespread clinical applications for implant procedures from the replacement of single teeth to extensive bone grafting for total reconstruction of maxillofacial skeleton needed as a result of tumor excision, trauma, etc. Implant dentistry has become an important tool for increasing the life expectancy of edentulous patients by improving the masticatory efficiency of the stomatognathic system. Patients with loss of teeth can be the victims of terrible social rejection, which includes loss of self-confidence, and self-esteem, resulting from the overshadowing aspect of endpoint atrophy of the maxillofacial skeleton.

Dentascan is dedicated post-scanning image evaluation software for the teeth and the jaw, which creates panoramic and paraxial views of the upper and lower jaw. Typical applications are pre-surgical planning for implants, information about the structure of the jaw bones and proximity to the critical anatomical structures at proposed implant sites like the mandibular canal, nasal cavity, incisive foramen, maxillary sinus. This technique provides a wealth of diagnostic information that is accurate, detailed and specific. The use of CT scans in conjunction with special reformatting software, dentascan readily meets the preprosthetic imaging objectives, i.e. identify disease, determine bone quality, quantity, implant position and implant orientation, and surpasses the short comings of conventional radiographic technique with detailed accuracy and reliability **(Fig. 6.1)**.

Quantity of Available Bone at Implant Site

Available bone is the amount of bone in the edentulous area considered for osseointegration of the implant. As a general guideline a distance of 1.5 mm is maintained for surgical error between the implant and any adjacent landmark. The chances of successful implantation are increased by more bone being available for anchorage and distribution of masticatory forces. Cortical bone is

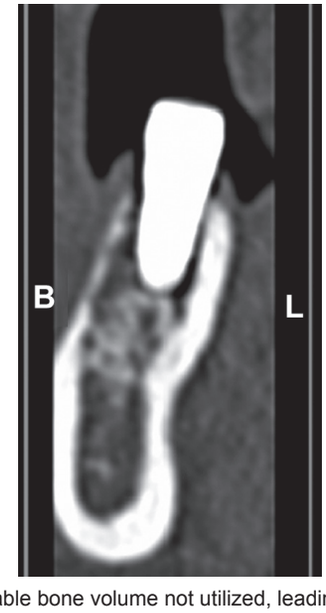


Fig. 6.1 Available bone volume not utilized, leading to chances of implant failure

best suited to provide support for implants. Accurate estimates of the alveolar bone height and width are mandatory for selecting the appropriate implant size and determining the degree of angulation of the edentulous alveolar ridge. The assessment of the angulation of the alveolar ridge provides information regarding the proper insertion path of the fixture. The angulation of the alveolar bone represents the root trajectory in relation to the occlusal plane.

Measurement of the height and width at the proposed implant site can be done on the films itself as it "life size", or it can determined upon the PC of the implantologist.

MAXILLA AND MANDIBLE

Maxilla

For maxillary anterior region the height of the available ridge can be calculated from the crest of ridge to inferior border of nasal fossa. For maxillary posterior region, the height of the ridge can be calculated from the superior border of crest of ridge to the inferior border of maxillary sinus **(Figs 6.2 and 6.3)**.

Mandible

For mandibular anterior region the height of the ridge can be calculated from the crest of ridge to inferior border of mandible. For mandibular posterior region, the height of the ridge can be calculated from the crest of ridge to superior border of inferior alveolar canal **(Figs 6.4 and 6.5)**.

Authors have observed that many radiologist provide the width by measuring from the outer cortical plates, which is not the actual width as it is the inner width from buccal and lingual cortical which is more reliable and accurate measurement **(Fig. 6.6)**. Buccolingual width of the ridge hence must be calculated from the inner buccal and inner lingual cortical plates from the crest of ridge.

There would be instances where a knife shape ridge may be present or where insufficient width would be present, until the implantologist perform osteotomy

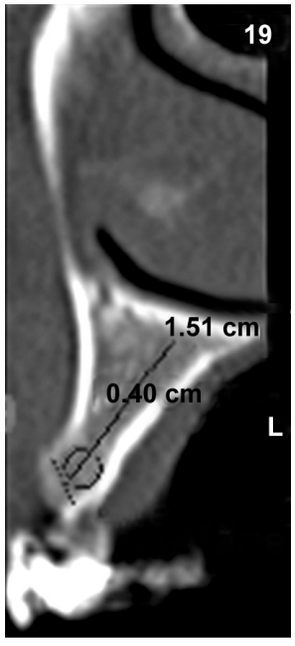


Fig. 6.2 Measurement for anterior maxilla

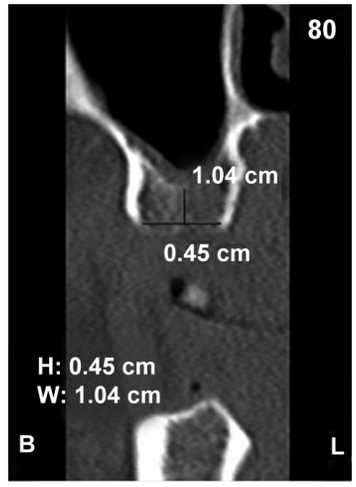


Fig. 6.3 Measurement for posterior maxilla

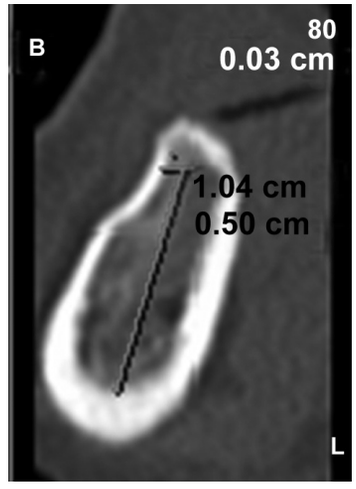


Fig. 6.4 Measurement for anterior mandible

to achieve adequate width. Dentascan software thus helps us to determine the amount of bone required to be removed during the osteotomy procedure for adequate acquisition of buccolingual width **(Fig. 6.7)**. This function can be performed by utilizing the linear scale tool present on the software.

An interesting clinically relevant classification can be used for determining the available bone as suggested by Chanavaz and Donazzan. The classification is termed as Chanavaz and Donazzan French Volumetric Classification (1986) **(Table 6.1) (Fig. 6.8)**.

This classification gives a clear idea about the type of bone available at the implant sites.

Presence of Type A bone will be difficult to obtain, if the patient do not report very early for implant. Generally the implantologist are encountered with Type B bone in their clinical practice. Amount of bone loss occurring the 1st year after the tooth loss is 10 times greater than the following years.

There are greater chances of Type A bone in maxillary posterior region as maxillary teeth are generally not lost at an early age as compared with mandibular first molar which tend to be affected by caries very early. Also it has been reported that atrophy of the maxillary arch proceeds at a slower rate than in the mandible. The posterior mandible resorbs approximately four times faster than the anterior mandible. The original height of available bone in the mandible is twice that of maxilla. The changes in anterior maxilla ridge dimension can be very dramatic both in height and width up to 70 percent especially

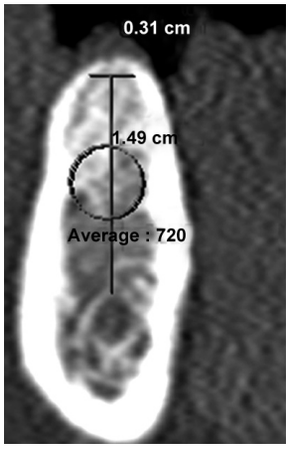


Fig. 6.5 Measurement for posterior mandible

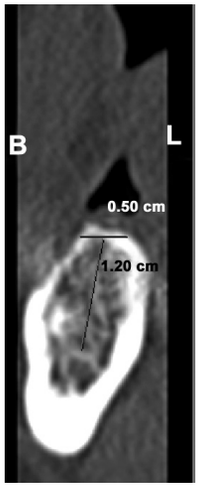


Fig. 6.6 Exaggerated width measurement due to outer cortical plate inclusion

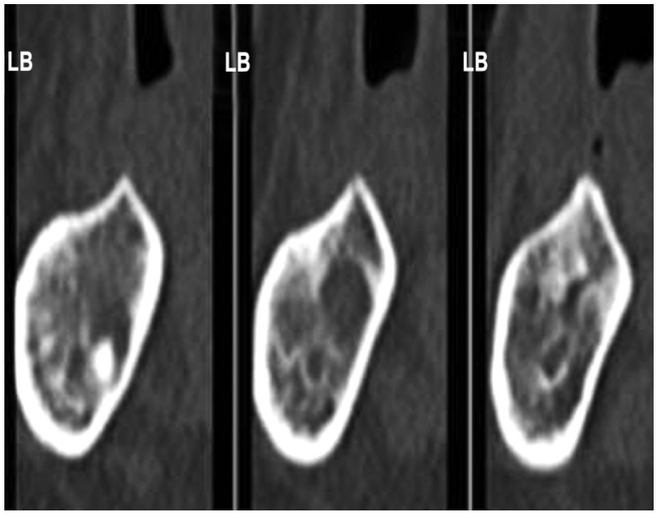
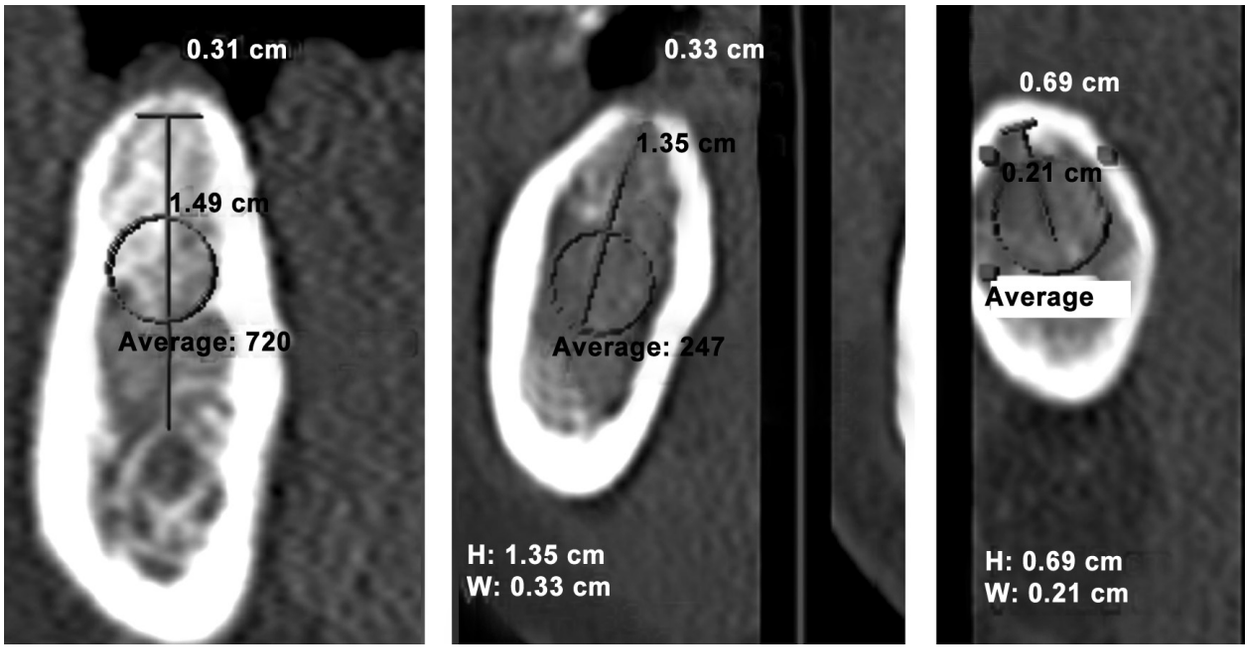


Fig. 6.7 Osteotomy required for knife shape ridge

Table 6.1: Chanavaz and Donazzan French Volumetric Classification

Category	*Dimension*	*Other features*
A	Height: 9 mm Width: 5 mm	Abundant bone in all dimensions with intact basal bone.
B	Height: 9 mm Width: 3 mm	Abundant bone except width, intact basal bone. Partially resorbed alveolar bone (After 5–9 years of extraction)
C	Inadequate bone	Totally resorbed alveolar bone. Intact basal bone
D	Severe bone atrophy	Totally resorbed alveolar bone. Partially resorbed basal bone except symphysis region and external oblique ridge



Type A bone Type B bone Type C bone

Fig. 6.8 Type of bone as seen on dental CT

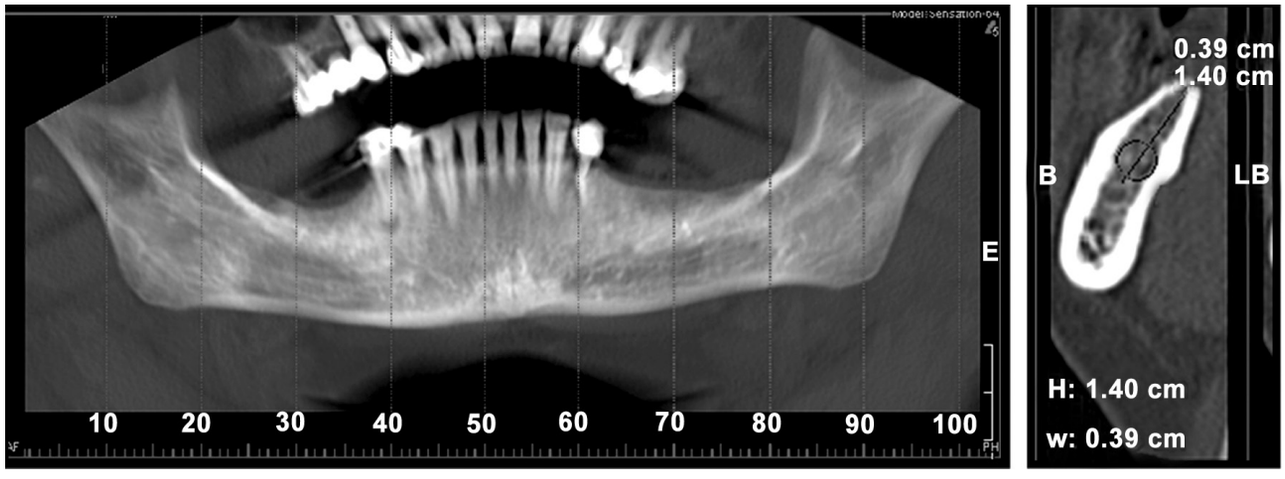


Fig. 6.9 Ridge pattern assessment seen best on paraxial image

when multiple extractions are performed. The residual ridge shifts palatally in the maxillary and lingually in the mandible as related to tooth position at the expense of buccal cortical plate in all areas of jaw **(Fig. 6.9)**.

Literature states that the decrease in bone begins in 4th decade and is linear.

Height or Width of Implant. Which is the Critical Parameter?

The width of implant decreases the stress by increasing the surface area. This may also reduce the length requirement. For every 0.5 mm increase in width there is an increased surface area between 10 and 15 percent.

Since the greatest stresses are concentrated at the crestal region of implant, width is more significant than the length for an implant design. In patients with triangular shaped cross-section, osteoplasty should be advised to obtain greater width of bone, although of reduced height. This rule was not applied in anterior maxilla as most edentulous ridges exhibited a labial concavity in the incisor area resulting a hour glass configuration **(Fig. 6.10)**.

Does Sex Affect the Quantity of Bone?

Female patients have a tendency for greater bone resorption. Following rapid initial resorption the rate decreases and then continues at about 0.1 mm per year in male and about 0.4 mm per year in female. This can be attributed to the decreased estrogen level in female patients. Females are more prone to osteoporosis and subsequently there is faster resorption of bone. The age associated bone loss is about 1 percent in women and 0.5 percent in males annually. Women represent a greater percentage of patients with residual ridge resorption than men.

Ridge Morphology

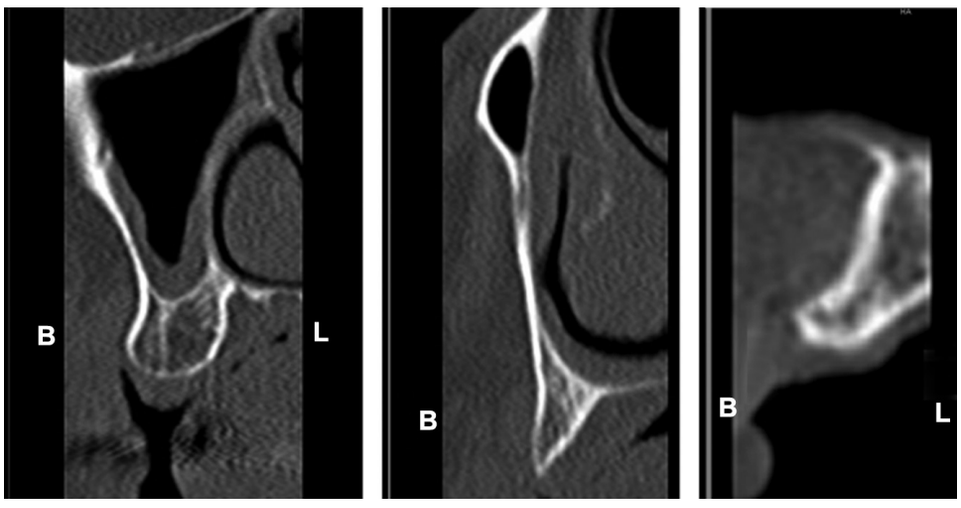
Buccolingual ridge pattern cannot be viewed on two dimensional radiographs, but dentascan provides with advantage of appreciating the type of alveolar ridge pattern present. Paraxial images provide the implantologist the appearance of ridge patterns like irregular ridge, narrow crestal ridge and knife shape ridge. Also loss of cortical plates can also be appreciated on paraxial images which cannot be seen on panoramic image. Buccal or lingual concavity also can be visualized on paraxial images.

In panoramic view ridge pattern cannot be examined as it is appreciated in paraxial image.

Ridge shape can be defined as the geometric form of the alveolar process or residual ridge. Ridge shape can be divided into rectangular, pyramidal and hourglass shape **(Fig. 6.10)**. In rectangular ridge shape the buccolingual width shape is similar in its inferior and superior horizontal dimensions. Pyramidal ridge shape the crestal horizontal dimension is narrower than the apical horizontal dimension. Hourglass form has a constricture of the alveolar process or residual ridge. This occurs when the crestal and apical horizontal dimensions exceed the buccolingual width. Risks of perforation increases due to undulating concavities, and thus dentascans prevent unnecessary surgical and postoperative complications. Mcginvney et al. and Schwartz et al. concluded that dentascan images more accurately reflected the true osseous topography and considered it as a valuable diagnostic aid. In case of compromised jaw bone in terms of quality and/or quantity of bone, panoramic technique is inefficient imaging tool. This dictates additional imaging in 2-D/3-D, especially when there is risks and doubts about treatment outcome, dentascan may prove indispensable.

Quality of Bone at Implant Sites

Density of available bone in an edentulous site is a determining factor in treatment planning, implant design, surgical approach, healing time, and initial progressive bone loading during prosthetic reconstruction. Literature suggests that the anterior mandible has greater bone density than the anterior maxilla. The posterior mandible has poorer bone density than the anterior mandible. The poorest bone quality in



Rectangular shape Pyramidal shape Hourglass shape

Fig. 6.10 Ridge morphology

the oral environment typically exists in the posterior maxilla and it is associated with dramatic failure rates. Periapical or panoramic radiographs are unhelpful when determining bone density because the lateral cortical plates often obscure trabecular pattern. CT is currently the only diagnostically justifiable imaging technique that allows at least rough conclusion about the structure and density of the jaw bones. Bone density can be evaluated using Hounsfield units (HU), which are directly related to tissue attenuation coefficients. The Hounsfield scale is based on density values for air, water, and dense bone which are assigned arbitrarily values of –1000, 0 and +1000 respectively. Techniques such as histomorphometry of bone biopsies or densitometry, quantitative ultrasound, dual photon absorptiometry, quantitative computed tomography although reliable and quantitative measures of bone density are not routinely feasible for the practice of implant dentistry **(Fig. 6.11)**.

The most critical region of bone density is the crestal 7 to 10 mm of bone. This determines the treatment protocol **(Fig. 6.12)**. The density decrease in the jaws is related to the length of time the region has been edentulous and not loaded appropriately.

Dentascans provides the clinician with Hounsfield values as an objective method of evaluating bone density for a proposed implant site. This was done only on the computer with help of the pixels tools present in the software. A circle can be formed at a height of 7 mm from the crest touching both the inner buccal and palatal/lingual cortical plates.

After the formation of circle, with the help of software, a circle histogram is demonstrated which provide the minimum and maximum pixels values. Along with it a standard deviation ware also given.

Haldun et al. advocated use of CT for determining bone quality and quantity. Absolute guidelines on these HU values cannot be provided, as the density observations will be scanner dependent and vary according to the particular exposure settings and window level applied. It is obvious that HU variation observed in the same jaw scan reflect local bone density variations with lower HU values for poor bone quality. Variability in values can alert the surgeon to modify the treatment plan so that primary stability in bone of less density is ensured and a longer healing period can then be planned.

Role of Templates in Implant Site Assessment

Slice number present on the scan cannot be duplicated into the oral cavity. Hence a technical problem arises in knowing the exact location of a particular site,which the radiologist have suggested for implant placement. This can be overcome by using the templates or radiographic markers/X-ray markers prior to scanning procedure. A template is a clear acrylic device that fits snugly over the residual teeth and alveolar process. An X-ray site marker allows the radiologist to pinpoint exactly where the ROI (region of interest) lies for the potential implant fixture. The marker material should be easily identifiable in the CT scan and not produce scatter artifact such as that seen in CT scans from metallic dental materials.

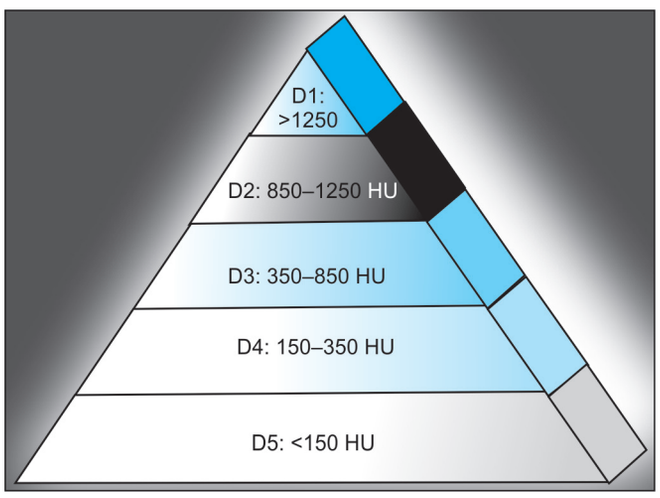


Fig. 6.11 Bone density based on HU values given by Misch D1: > 1250 HU; D2: 850–1250 HU; D3: 350–850 HU; D4: 150–350 HU; D5: <150 HU

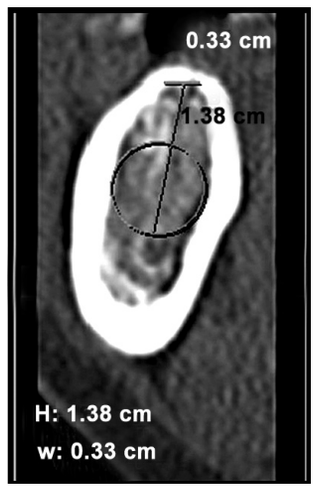


Fig. 6.12 Density measurement on dental CT software at a distance of 7 mm as advised by misch

By using radiographic markers at the time of scanning, the surgeon and restorative dentist can plant the exact placement of implants with respect to embrasures, cement-enamel junction of adjacent teeth and emergence profiles relative to the planned contour of the anticipated prosthetic restoration.

Recent years much software for implant planification and navigation are developed. Meticulous protocol is needed to computered implant planning whichever software is choosen (Verstreken et al., 1996, 1998). The two principal softwares created for dental implant planification are called Simplant and Nobelguide, they are mainly designed for surgical act, and a work tool to show dental surgeon the way in implant installation called Robodent (Treil et al., 2009). These different examples should illustrate this topic.

Simplant

Study begins by making articulated models (Corcos, 2007). Then a wax setting simulates the final dental prosthesis and allows surgeon to visualize technical constraints. He visualizes imperatives implementation of implant prosthesis. Then the radiological guide derived from prosthetic model can be achieved. Either radiopaque commercial false teeth are inserted or barium sulfate balls are included in wax. While different barium sulfate concentrations are adjusted, we can precisely differentiate and individualize masks of different density. A cylindral cavity focused on occlusal tooth's side and emerging from cervical side makes the main tooth axis visible.

CT Scan

Patients wear the radiological guide during the CT scan acquisition. Dental arches must not be in contact together, in order to make the CT scan data processing easily. Radiologist has to take care of:

- Stability and well-positioning radiological guide, with control of accommodation or adjustment with mucous membrane.
- Determination of axial plane that is parallel to the teeth occlusal area.
- Visibility of teeth occlusal area, that has to be full visible.

Nobelguide

Nobelguide is the same concept as Simplant one.

Robodent

Softwares such as Nobelguide or Simplant give way to undeniable surgical help, particularly for surgical step.

But it requires a rigourous procedure and laboratory time to transfer all the data of preimplant check-up. New tools recently appear that leads surgeon's hand while implants installation, these tools are already used in neuro-surgery, maxilla-facial surgery and otorhinolaryngology. Softwares enable a real-time interface between preimplant plan and rotating instrumentation for implant site.

In addition the surgical tool named Robodent is a navigational instrument. Surgeon can also follow the drills progress on line in comparison to contiguous anatomical structures. It pilots the surgeon's hand while he drills the bone. Optical tracer is fixated on wax prosthesis, as well as on the drill. Then their motion is captured by a camera and worked out with three-way correlation. The more advanced systems use to optical tracers. Optical tracers, passive (ceramic balls) or active (LED) according to system secured with dental arch. Then their motion is captured by a camera and worked out with three-way correlation. It is a real-time tool to follow the drill in anatomical pieces. Prosthetic analysis happens as usual. A diagnostic wax model is made for functional and esthetic necessities. Radiological guide as a gutter, secured with facial arch contenting radiological marks is adapted to dental arch. This guide should serve as a support for location system in surgical navigation. The CT scan is acquired with this system on dental arch. A temporary removable prosthesis should be used for toothless jaw; it has to be secure and motionless meanwhile. A CD is burned with CT images in DICOM format, given to dentist. He validates the choice of anatomic sites for implants with analyze and planification software.

Purpose of Template (Table 6.2)

- Selection of appropriate implant site
- Decrease degree of distortion
- Determine precise measurements
- Transfer the data to surgical site and used for accurate determination of location and angle of placement of the implant.
- Avoids cortical plate perforation in thin buccolingual sites.
- Determines vertical placement of implant.

Table 6.2: Literature guide for fabrication of various radiographic templates

Sr No	*Author*	*Name of technique*	*Reference*
1.	Simon H	Transitional implants The use of transitional implants requires meticulous treatment planning and additional chairtime. They provide support for an immediate fixed restoration and facilitate accurate implant placement with improved stability of the surgical template and enhanced visibility of the surgical sites.	J Prosthet Dent 2002;87:229-32.
2.	Cehreli et al.	Dual-purpose guide Dual-purpose guide with interplaced stainless steel surgical guides. The use of such guide channels assists the surgeon during site preparation. The drill guides are machined to allow consecutive surgical drills to be used without changing the implant angulation during surgery	J Prosthet Dent 2002;88:640-3.
3.	Takeshita et al.	Stent with barium sulfate and stainless steel tubes. The barium sulfate in the stent depicts the outline of the predesigned superstructure, and the stainless steel tubes indicate the intended location and inclination of the implants on the computed tomographic scans. In addition, this stent can be used as a surgical stent to guide the pilot drill to the desired site	J Prosthet Dent 1997;77:36-8
4.	Cehreli et al.	Bilaminar dual-purpose stent This stent is designed for use particularly in D4 type bone in which malpractice may compromise the success of implants	J Prosthet Dent 2000;84:55-8
5.	Pesun et al.	Gutta percha markers Fabrication of a radiographic guide for a patient with severely worn dentition. Chair and laboratory time are reduced because one guide can be used for both radiographs and surgery. The guide is easily fitted to the existing dentition and allows evaluation of the contours of the final restoration in the patient's mouth by the patient, the restoring dentist, and the surgeon.	J Prosthet Dent 1995;73:548-52.
6.	Ku et al.	Vaccum former radiographic stent A simple method of fabricating a vacuum-formed matrix filed with clear acrylic resin and a gutta-percha marker. The matrix can be used not only as a radiopaque marker for evaluation but also as a surgical guide during the surgical stage for single implant therapy.	J J Prosthet Dent 2000;83:252-3.
7.	Miles et al.	Gutta percha In office technique of radiographic stent with gutta percha	

Gutta percha is an ideal material. It is non-metal, radiopaque, readily available in almost all dental offices and inexpensive. Lead foils placed preoperatively into the oral cavity or in existing denture is another material used for implant site assessment **(Figs 6.13 and 6.14)**. Fabrication of radiographic stents is a useful method for determining the exact location of proposed implant site. According Abraham JJ et al. markers should be 1 to 2 mm in diameter, vertically oriented, and without mesial/distal tilt. They should be attached to gingival surface of the stent and places as far into the buccal sulcus as possible. Because most dentists are unfamiliar with CT scanning the radiologist can be instrumental in helping the dentist place the markers in manner that will yield the greatest amount of information. Fabrication of various radiographic stent is beyond the scope of this textbook, but for further reading on this topic, table no. 11 will provide useful information.

Streak Artifacts

Streak artifacts from dental restorative materials, which interfere with visualization of bone on direct axial images, do not degrade the reformatted cross-sectional images because the artifacts are not usually projected at the level of the alveolar process **(Fig. 6.15)**.

RADIATION DOSE

Dentascan gives a radiation dose of 14.10 mGy for a total scan period of 7.98 seconds at 90 kV and 120 mAs. This radiation dose is comparatively less compared to radiation dose give by dental CT in the past where values above 200 mGy was calculated.

This radiation dose can be further reduced by decreasing the kilo voltage, milliampere seconds and increasing the slice thickness. The disadvantage of changing these parameters would be that it would decrease the image resolution thereby affecting the image quality.

Conventional radiographic techniques have a low radiation dosage but they do not furnish the osseous details as impeccably as dentascans do and so by providing such accurate details it increases the success rate thereby reducing the chances of failure of implants.

Fig. 6.14 Lead template seen on dental CT

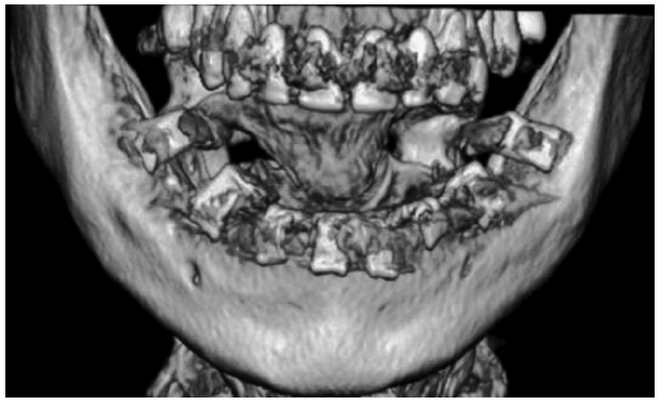


Fig. 6.13 Lead template place prior to scanning

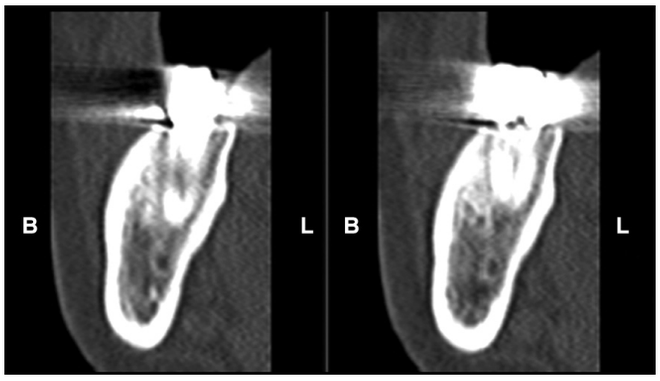


Fig. 6.15 Streak artifact not affecting the image quality and interpretation

Advantages of Dentascans

- CT always images the entire arch.
- It allows for more accurate visualization of anatomic structures without superimposition.
- It allows for continuous view of surface tomography.
- Soft tissue detail is preserved.
- Patient comfort is excellent. No hyperextension of neck required during scan.
- Duration of scan is in seconds. Hence it is very comfortable to patients.
- It produces lower radiographic exposure than combination techniques and allows reconstruction from original data versus re-exposure of patient.
- It allows for verification of site and orientation of reconstruction.
- Thin section of images can be obtained.
- Film based tomography cannot show the range of contrast that is displayed on CT.
- The CT examination typically produces 50 to 100, 1 to 2 mm cross-sectional images at defined locations around the dental arch in addition to panoramic, axial, and other views.
- It permits preoperative evaluation for maximal use of available bone.
- It allows visualization and accurate location of developmental defects, foreign bodies, undercuts and osseous pathology.
- Only CT can present images in "LIFE SIZE" so that precise measurements can be made.
- Only CT can sample the density of bone over the selected regions of interest and compare these estimates with bone in the cervical spine or some other site.
- Streak artifacts from dental restorative materials, which interfere with visualization of bone on direct axial images, do not degrade the reformatted cross-sectional images because the artifacts are not usually projected at the level of the alveolar process.

Disadvantages

- Patient movement must be avoided for the entire scan.
- The technique and equipment are less accessible.
- Cost is greater than for conventional radiographic techniques.
- Radiation dose is greater compared with conventional techniques.

Indications

1. Posterior mandibular therapy when conventional radiographs show insufficient bone above the mandibular canal or the canal cannot be visualized.
2. Posterior maxillary area when conventional radiographs show inadequate bone.
3. Anterior maxillary implant therapy when multiple implants are necessary.
   - Can determine size and location of incisive canal ; CT will reveal presence of adequate bone anterior to the canal for implant placement.
   - Determines location of cortical bone in floor of nasal cavity and maxillary sinuses for anchoring apical aspect of maxillary implants.
   - Facilitates planning of angulation and length of implants when configuration of edentulous ridges complicates implant placement.
   - Evaluates bone resorption patterns to determine if esthetic or phonetic compromises may be necessary.
4. Complete maxillary and mandibular implant therapy.
5. Evaluation of buccolingual ridge dimensions not available on conventional radiographs.

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Chapter 7

Dental CT in Periodontics

Pratik Dedhia

Dental CT imaging techniques could be beneficial in assessing periodontal breakdown and its marked superiority in the diagnosis of furcation areas with greater resolution, repeatability, and accuracy compared to the clinical examinations performed.

Periodontal disease begins when bacteria-laden plaques accumulate around the teeth. This plaque may harden into calculus, a tough gritty material that is difficult to remove. Bacterial overgrowth can produce gingivitis, which may progress to a periodontitis in which the periodontal ligament and other supporting structures of the tooth are affected. The periodontal ligament is responsible for holding the tooth in its bony socket and helps provide the tooth with small degrees of motion or "give" within the socket. The periodontal ligament on plain film appears as a radiolucency between the cementum of the root and the lamina dura of the bony socket **(Fig. 7.1)**. The fibers of the periodontal ligament, which radiate from the cementum of the root into the gingiva, serve to attach the gingiva to the tooth.

When gingivitis becomes severe, this attachment weakens and bacteria can attack the periodontal ligament. The ligament can be gradually destroyed, creating a space called a periodontal pocket between the lateral wall of the root and the bony socket. Bacteria accumulate in the periodontal pocket and cannot be reached with routine dental hygiene. The attack can continue until the surrounding bone becomes resorbed and the tooth is lost. Radiographically, this bone loss appears as a radiolucency adjacent to the surface of the root that can travel down as far as the root apex **(Fig. 7.2)**.

PERIODONTITIS AND MAXILLARY SINUS

Periodontal disease may be a frequently unrecognized cause of maxillary sinus disease. There is a twofold increase in maxillary sinus disease in patients with periodontal disease and have shown a causal relationship. Recognition of this relationship may have an impact on the clinical management of patients, particularly

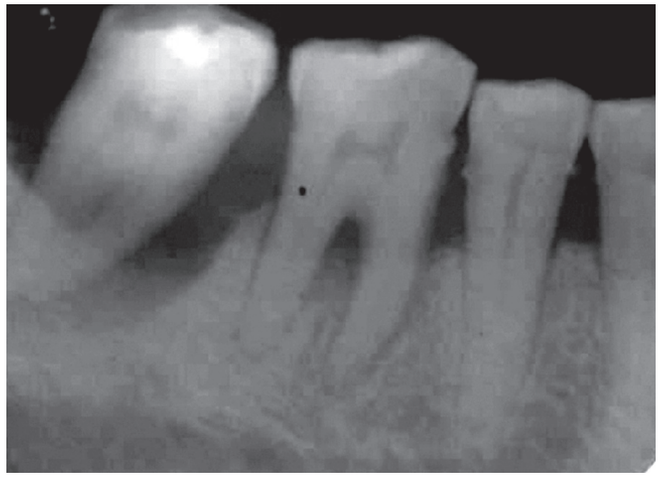

Fig. 7.1 Bone loss seen on conventional periapical radiograph

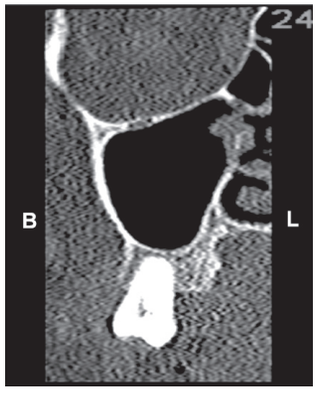

Fig. 7.2 Horizontal bone loss seen on dental CT

those planning implant surgeries. Such findings may also provide a clue to the true cause of maxillary sinus disease, particularly when the sinus disease is focal in the inferior aspect of the sinus and in the surrounding areas of periodontal disease **(Figs 7.3 and 7.4)**. The maxillary sinus can reach far mesially and between the roots of the molars and premolars.

Due to the close relationship with these other structures, the maxillary sinus can be easily affected by inflammatory conditions and cystic lesions of the adjacent teeth. Much emphasis has been recently placed on the osteomeatal unit as a cause of sinus disease, but dental disease may also be a source of problems in patients. Recognizing this may have an impact on the clinical management of patients, particularly those planning implant surgeries. Because of the intimate relationship between teeth and maxillary sinus, periapical/periodontal infections might result in reactive mucosal response within the sinus. Maxillary sinus mucosal thickening is twice as common in patients with dental disease as in the general population and odontogenic sinusitis accounts for approximately 10 to 12 percent of all cases of maxillary sinusitis. Failure to recognize the tooth as a cause of sinus disease can result in incomplete or inadequate therapy and mismanagement of these conditions.

Fig. 7.3 Endo perio lesion seen on dental CT

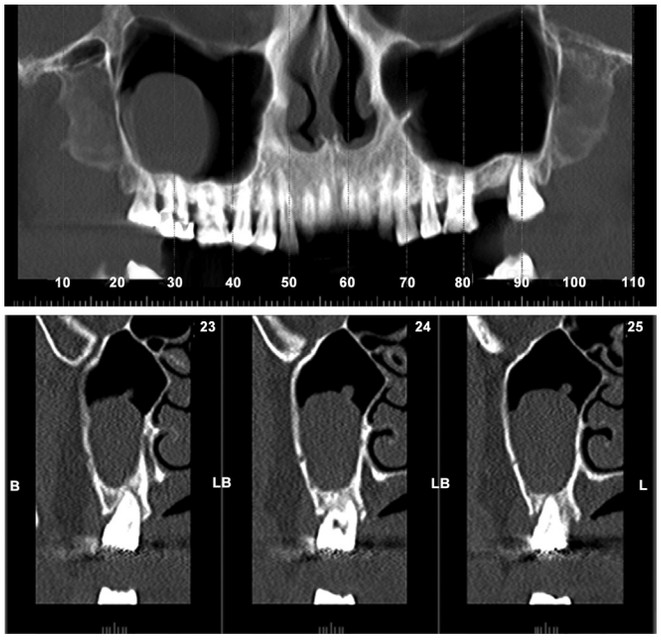

Fig. 7.4 Case of periodontitis with maxillary sinus pathology as seen on panoramic and paraxial image

Although surgical interventions involving the maxillary sinus are increasing, the presurgical planning continues using two-dimensional radiographs for maxillary sinus visualization. Considering the anatomical variability related to the surgical site, including the maxillary sinus floor and its intimate contact with the maxillary posterior teeth, observations on the three-dimensional structure are most useful in relation to implant surgery and sinus grafting.

ROOT EVALUATION

The roots of the teeth are commonly superimposed on intraoral radiographs, particularly in the molar region. As a result, it can be difficult to determine if a root is eroded due to a lesion or if the bone in the furcation (between the roots) or surrounding the root is abnormal. It is also difficult to tell if a lesion involves all of the roots of a tooth or only one and to tell which surface of the root is involved. This is important because it allows the dental surgeon to determine his or her treatment plan and to decide if an apicoectomy (root removal) is needed to gain access to the diseased area. It also helps the dentist to preoperatively decide if there is sufficient bone surrounding the roots to render the tooth salvageable **(Figs 7.5 to 7.8)**.

Comparing the lesions of specimens with intraoral radiographs and dental CT reformatted images, the dental and periodontal pathoses and topographical structures are more clearly observed in the dental CT

reformatted images, providing the possibility of more applications of reformatted images to clinical dentistry.

In conclusion, this chapter has demonstrated, through a series of examples, the effect that dental CT programs have had on the way we image the jaw today. These programs have created not only a new way of looking at the jaw but also a new referral pattern with dentists. It is important that we work closely with our dental colleagues,

Fig. 7.5 Periodontal infection involving right maxillary third molar

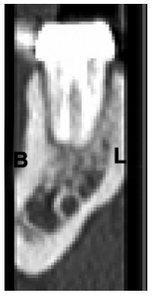

Fig. 7.6 Bone loss around mesial and distal root clearly demonstrated on paraxial image

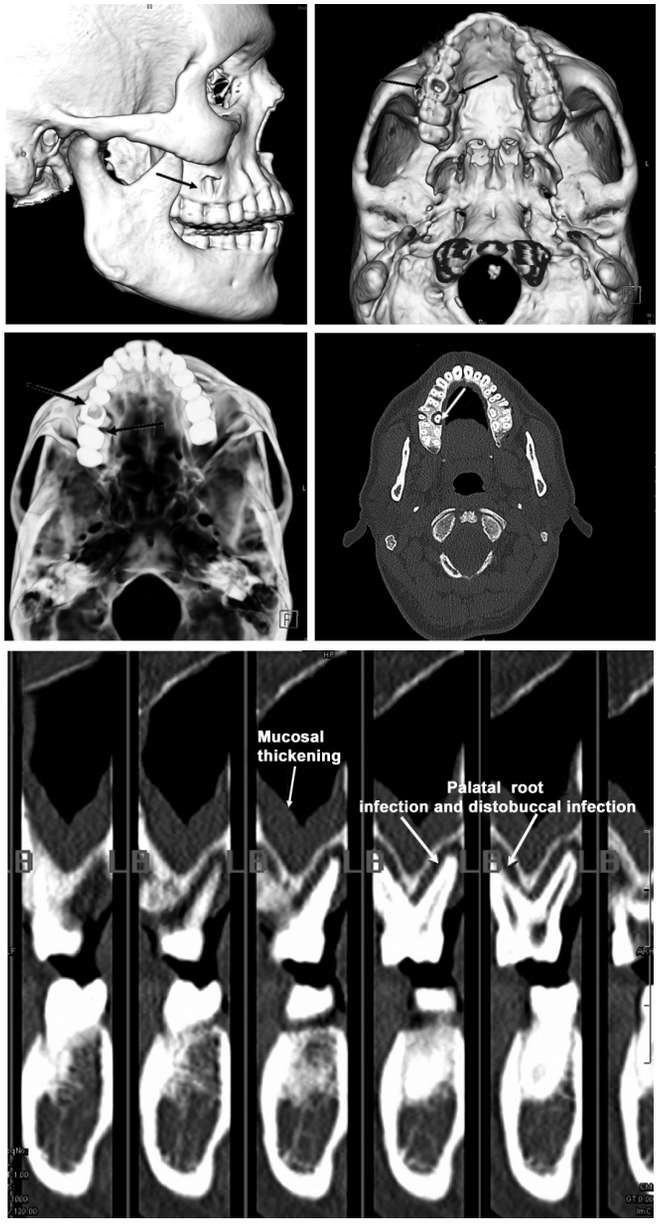

Fig. 7.7 3-D image showing loss of buccal cortical plate due to periodontal infection

learn their language, and assist them in understanding the imaging modalities available to them.

PERIODONTAL CASES

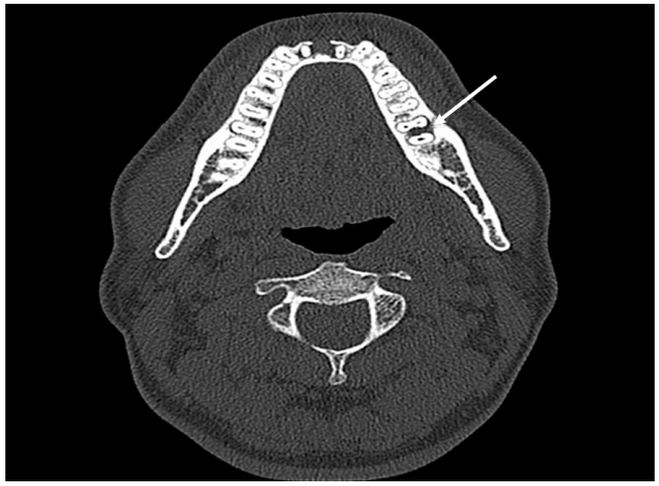

Fig. 7.8 Bone loss in furcation area of mandibular left first molar

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Chapter 8

Dental CT in Oral and Maxillofacial Surgery

Prashant P Jaju

Dental CT has proven its mettle even in the field of oral and maxillofacial surgery. Perfect assessment of the extend of lesion, along with accurate diagnosis and efficient treatment planning is provided by dental CT. Before entering the operating room, oral surgeon becomes well acquaint with the three dimensional anatomy of the patient's oral cavity, thereby tremendously improving the surgical efficiency, limiting postoperative complications and providing excellent healing.

Indications of dental CT in oral and maxillofacial surgery includes:

- Third molar position assessment and its relation with mandibular canal/maxillary sinus **(Figs 8.1 to 8.3)**.
- Supernumerary teeth assessment, ectopic tooth positioning can be accurately determined.
- Displaced root pieces in the anatomical spaces can be accurately determined **(Figs 8.4 and 8.6)**.
- Buccolingual and mesiodistal extend of benign and malignant pathologies can be accurately predicted **(Fig. 8.5)**.
- Impacted canine location can be determined **(Figs 8.10 to 8.12)**.
- Pathologies involving maxillary sinus is easily identified **(Figs 8.7, 8.13 and 8.14)**.
- Maxillary and mandibular fracture extend is identified **(Figs 8.8 and 8.9)**.

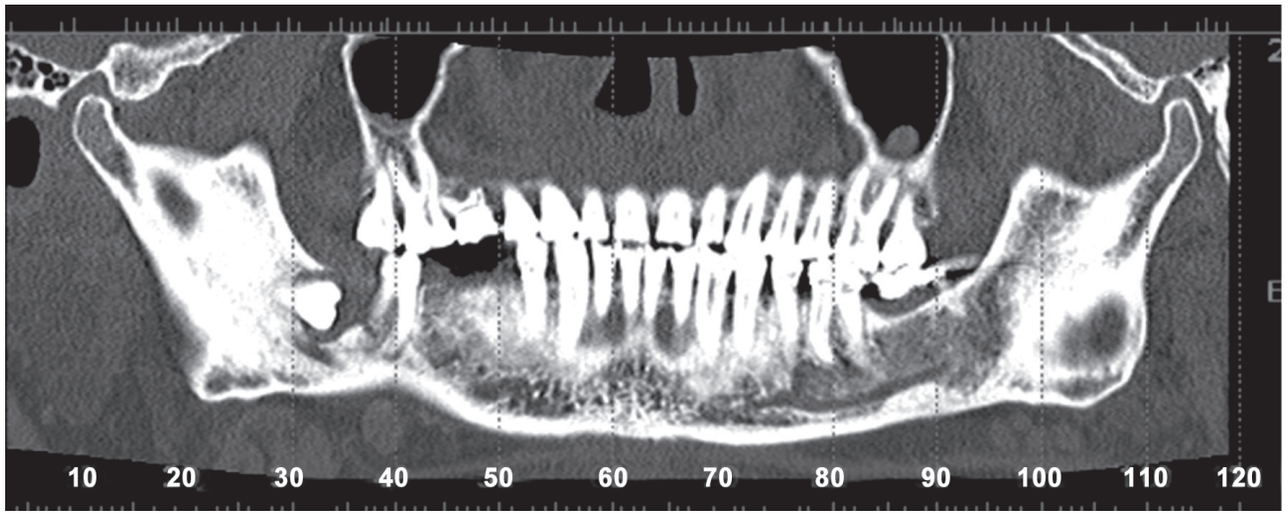

Fig 8.1 Dentigerous cyst with horizontally impacted 48

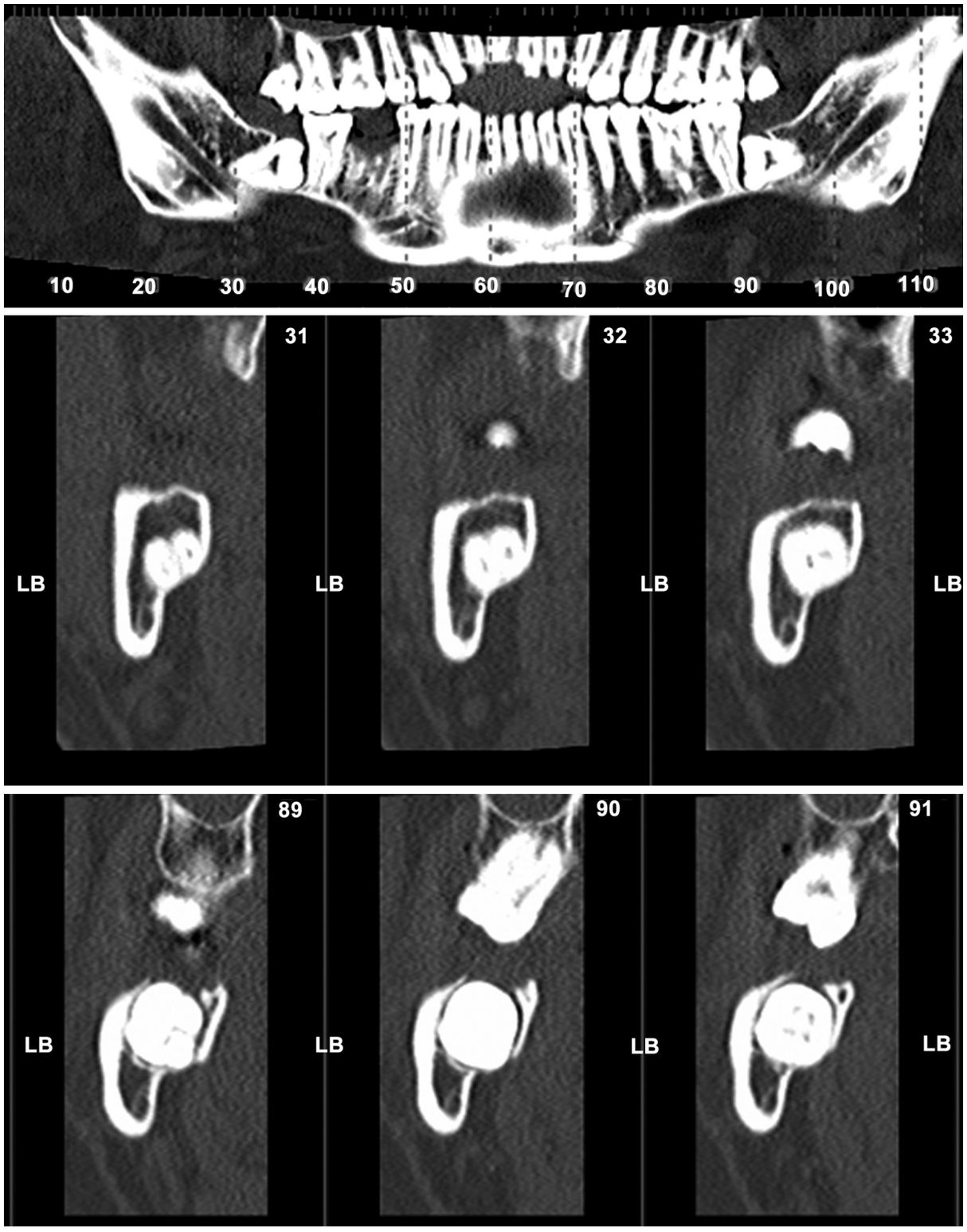

Fig. 8.2 Horizontally impacted 38,48. Paraxial images shows the positioning of 48 along with its relation to mandibular canal. Also paraxial image shows lingual cortical plate perforation with horizontally impacted 38

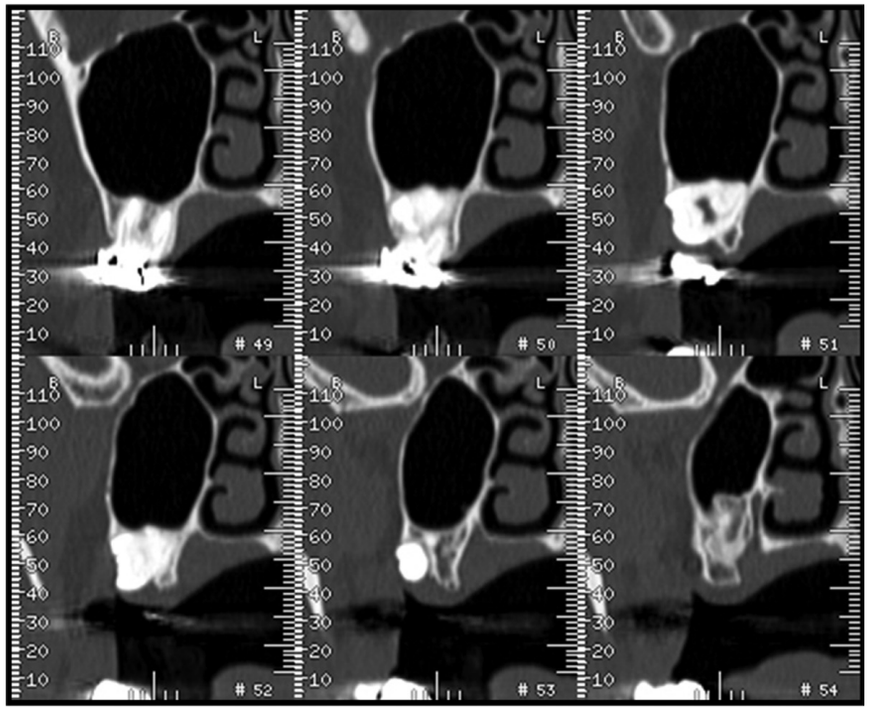

Fig. 8.3 Impacted maxillary third molar

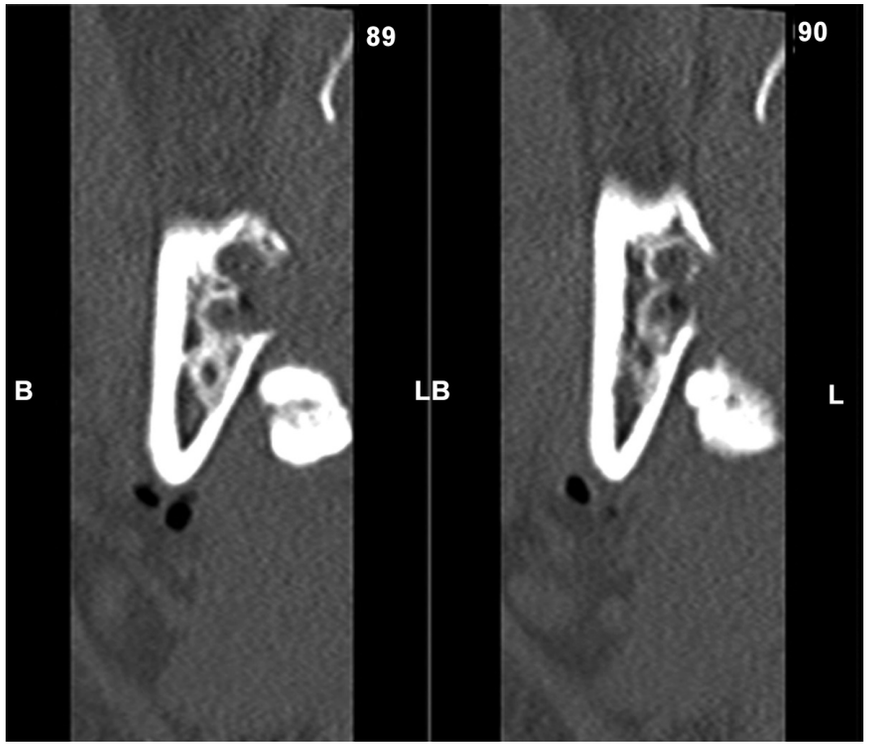

Fig 8.4 Positioning of lingually displaced root pieces can be accurately determined

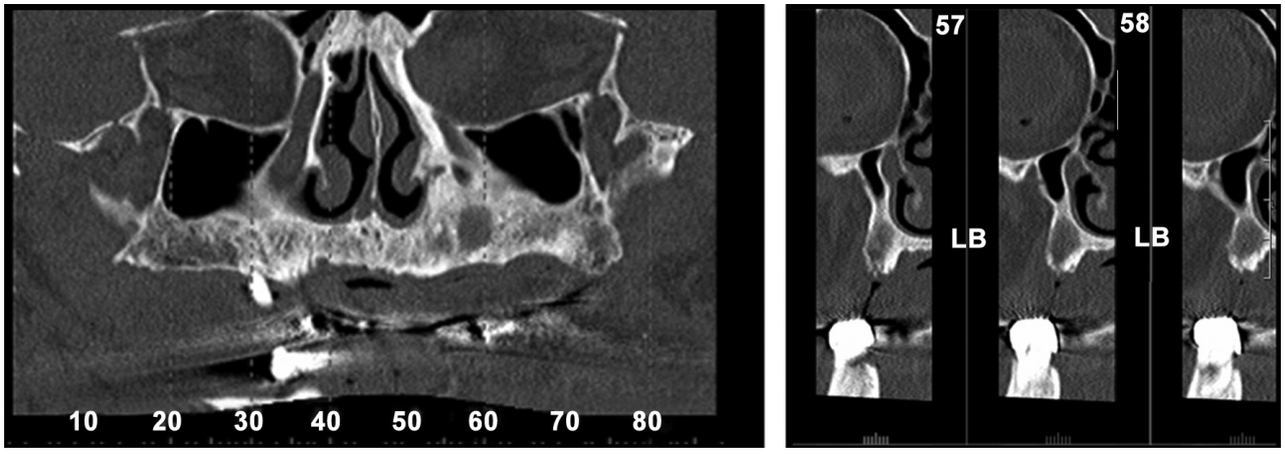

Fig. 8.5 Residual cyst seen on slice number 56–71

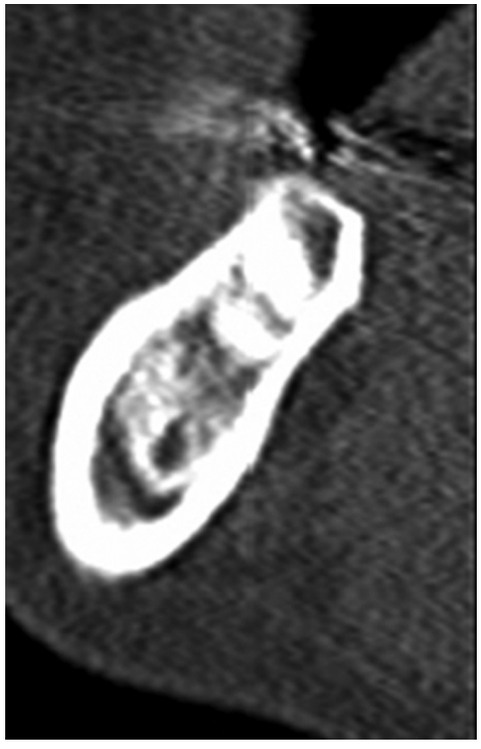

Fig. 8.6 Precise location of root pieces seen on paraxial images

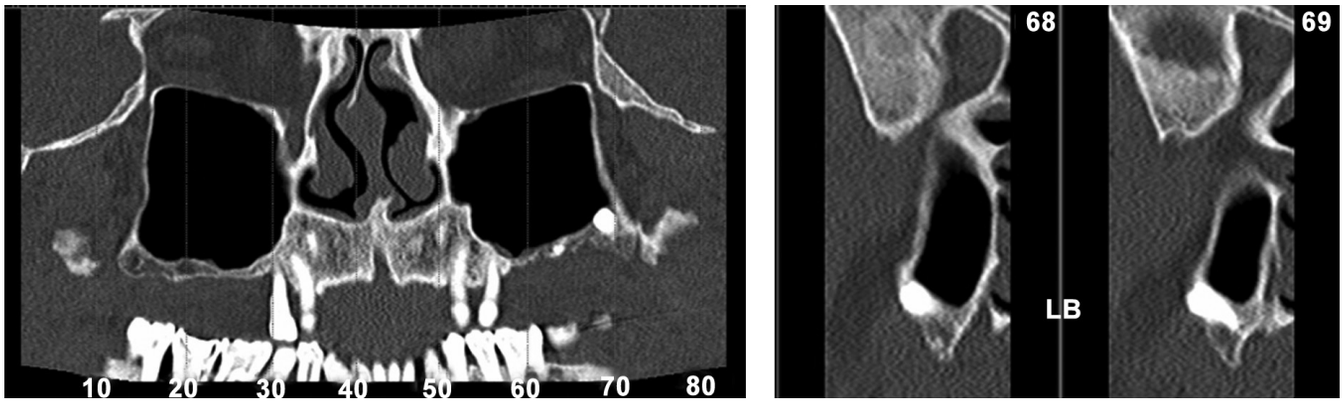

Fig. 8.7 Root piece displaced in left maxillary sinus. Accurate position determined on paraxial image

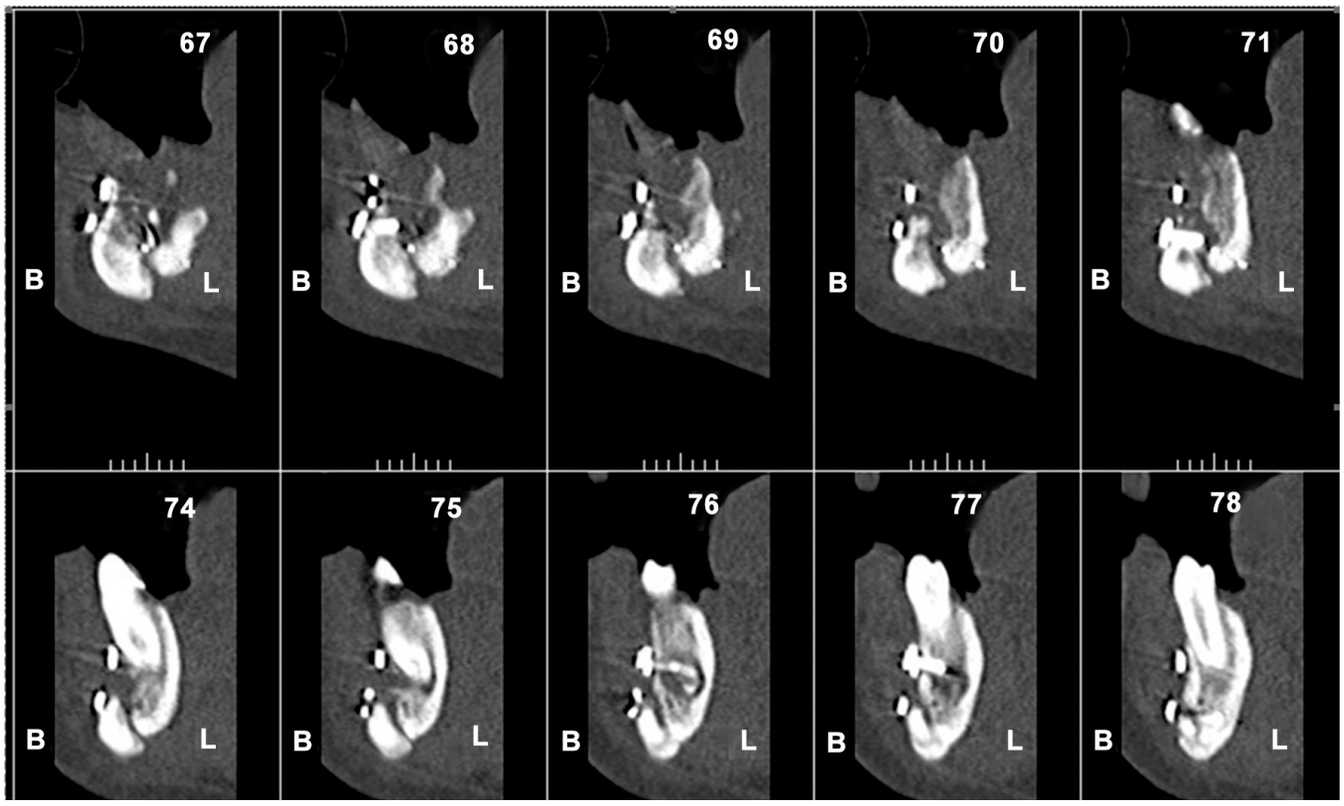

Fig. 8.8 Fracture of mandible

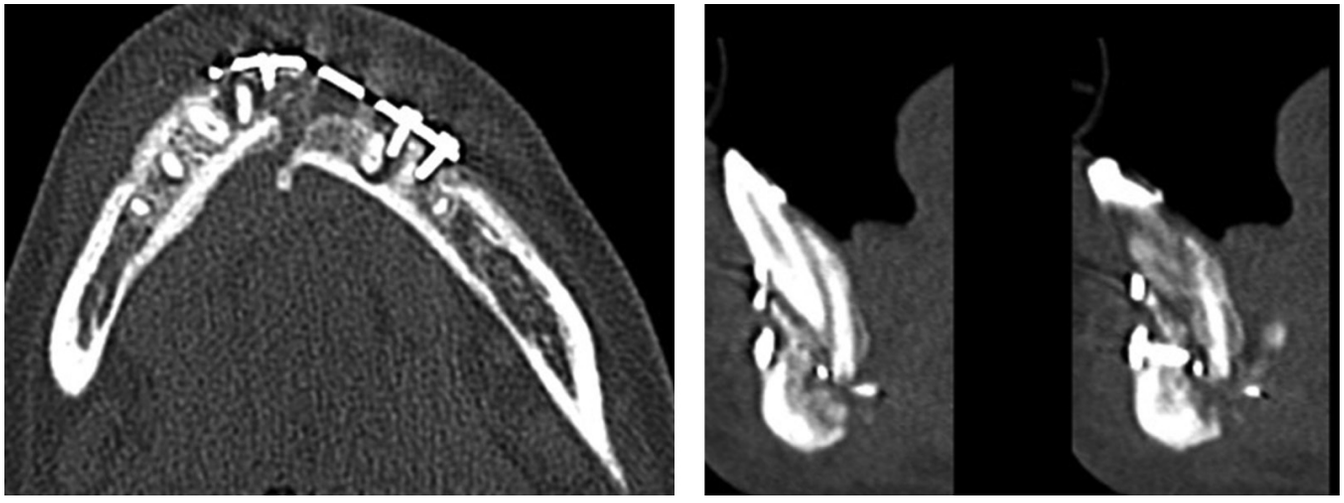

Fig. 8.9 Fracture of mandibular symphysis

Fig. 8.10 Precise location of impacted canine seen on axial slice

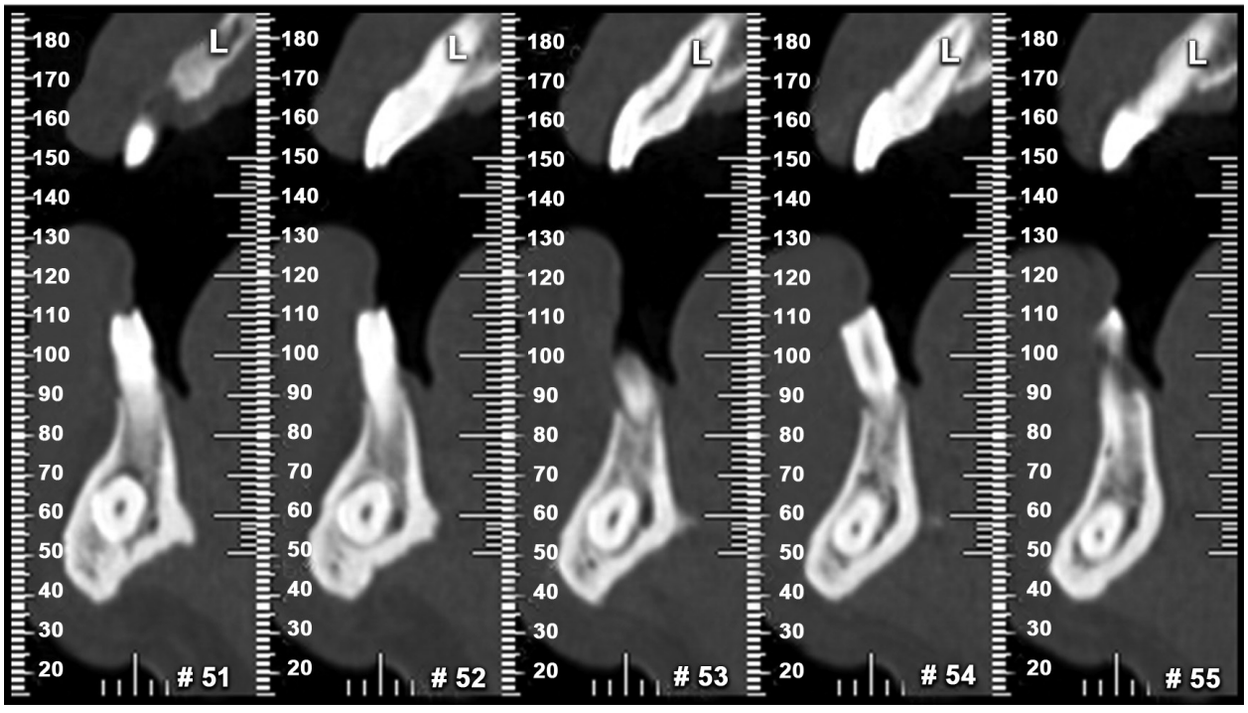

Fig. 8.11 Location of impacted mandibular tooth precisely located on paraxial slices

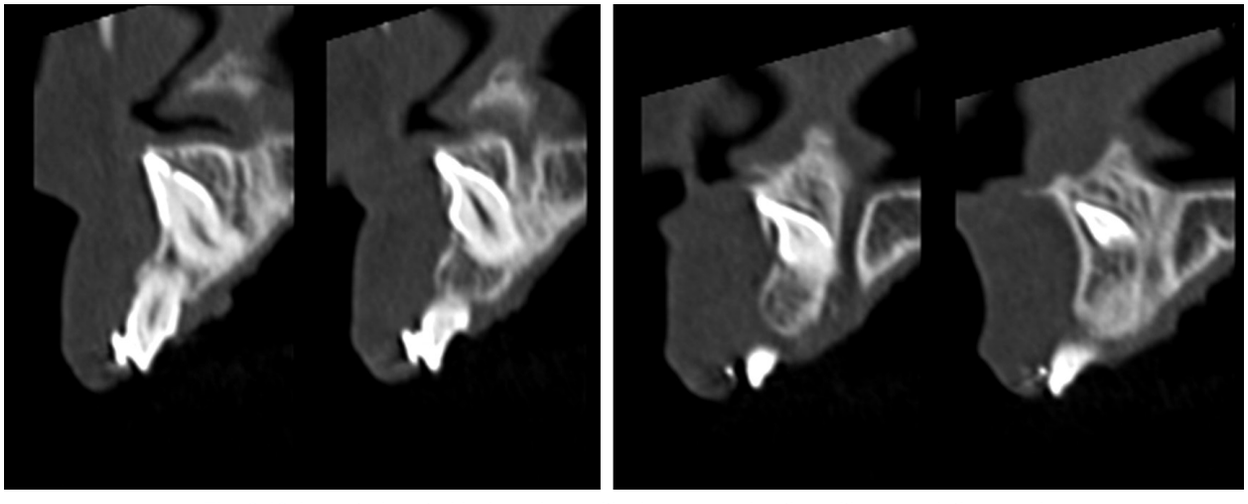

Fig. 8.12 Impacted central incisor along with close approximation with nasopalatine canal

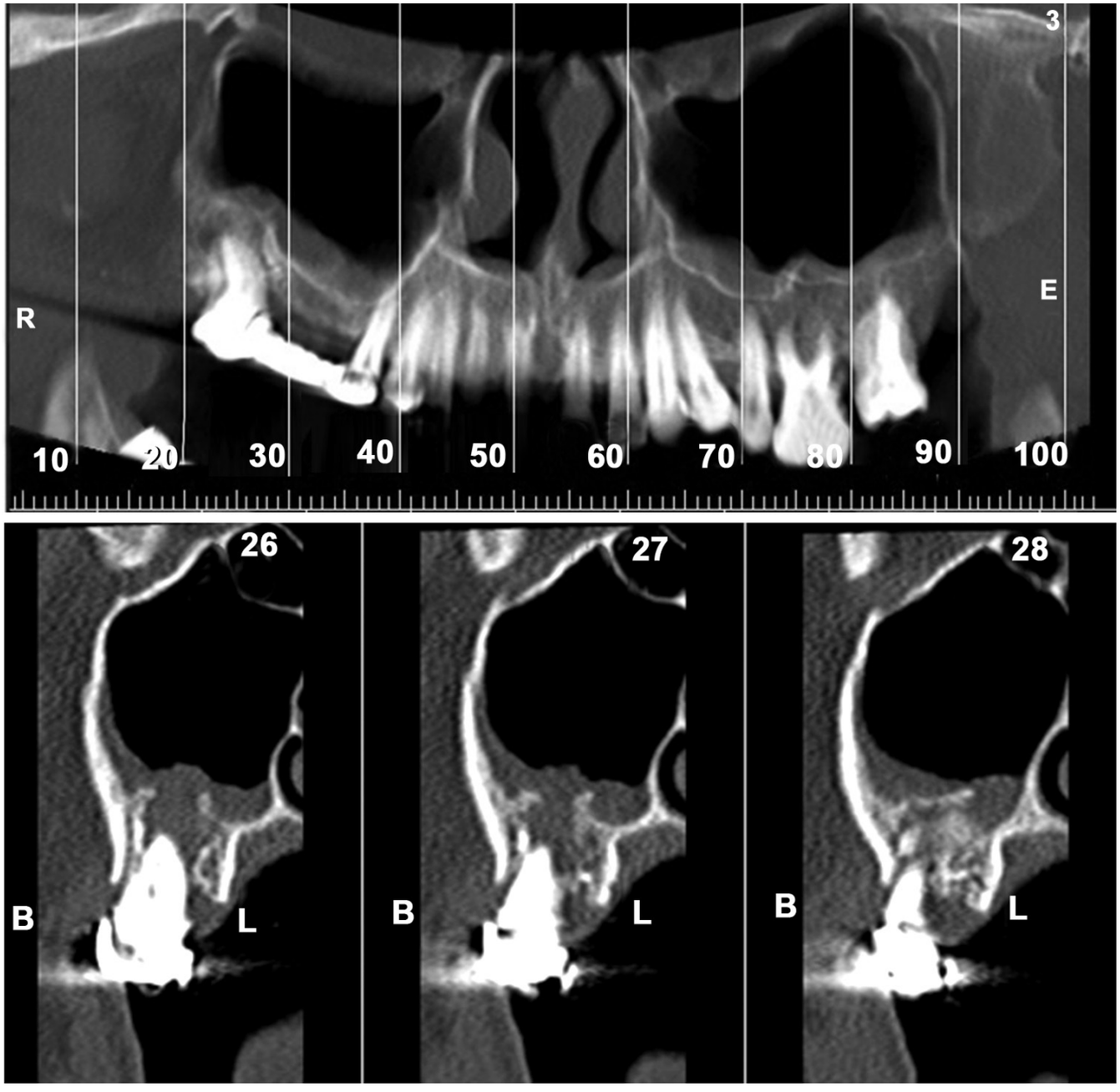

Fig. 8.13 Maxillary sinus perforation accurately seen on dental CT

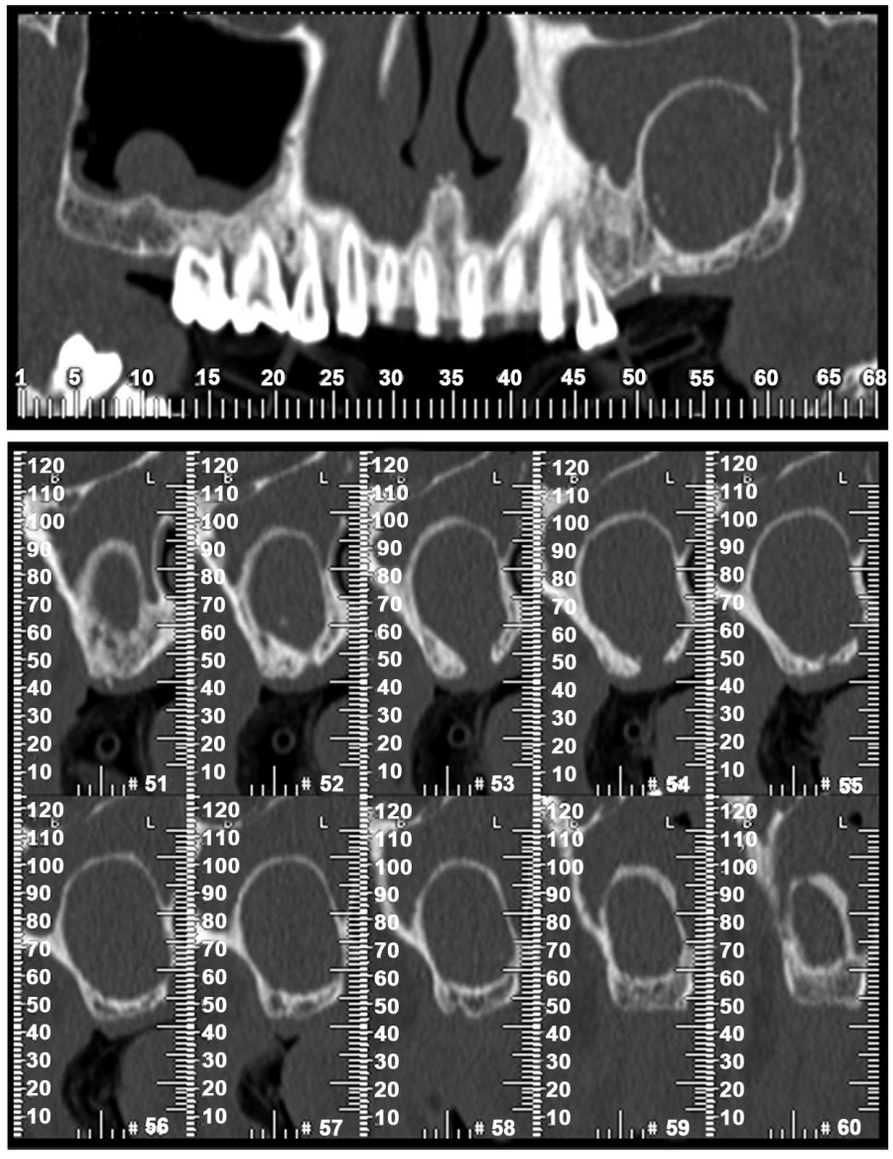

Fig. 8.14 Residual cyst involving left maxillary sinus with complete haziness

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Chapter 9

Dental CT in Endodontics

Sushma P Jaju

Radiology is the need of the hour for field of endodontics. Root canal treatment is the number one procedure performed in every dental clinic and radiological aspect is the most crucial step for successful endodontic treatment.

Radiology is useful for following purpose:

1. Detection of caries **(Fig. 9.2)**.
2. Determination of periapical lesions **(Figs 9.3 and 9.4)**.
3. Determination of root canal length for endodontic purpose.
4. Assessment of root canal fillings **(Fig. 9.1)**.
5. Assessment of number of canals in teeth **(Fig. 9.7)**.

Neither two dimensional imaging can depict the buccolingual extend of caries nor it is able to tell anatomical variations in root canal morphology in this plane.

This can be easily overcome by dental CT.

Proper access cavity preparation and obturation form the keystone for successful root canal therapy. Nearly 60 percent of the failures are apparently caused by incomplete obliteration of the radicular space. Root canal variations predispose to inadequate root canal preparation and should be recognized before or during treatment. There are innumerable instances of variations in root canal anatomy like, extra canals which are missed by a novice operator which ultimately leads to root canal failure. Extra canals are a common findings and missing of these canals leads to endodontic treatment failure. Hess pointed out that 54 percent of his 513 maxillary molar specimens had four canals. Mandibular molars also exhibit secondary root canals, over and above the traditional three. Although as many as five canals and as few as one and two canals rarely occur in mandibular molars, four canals are not unusual. Premolar teeth

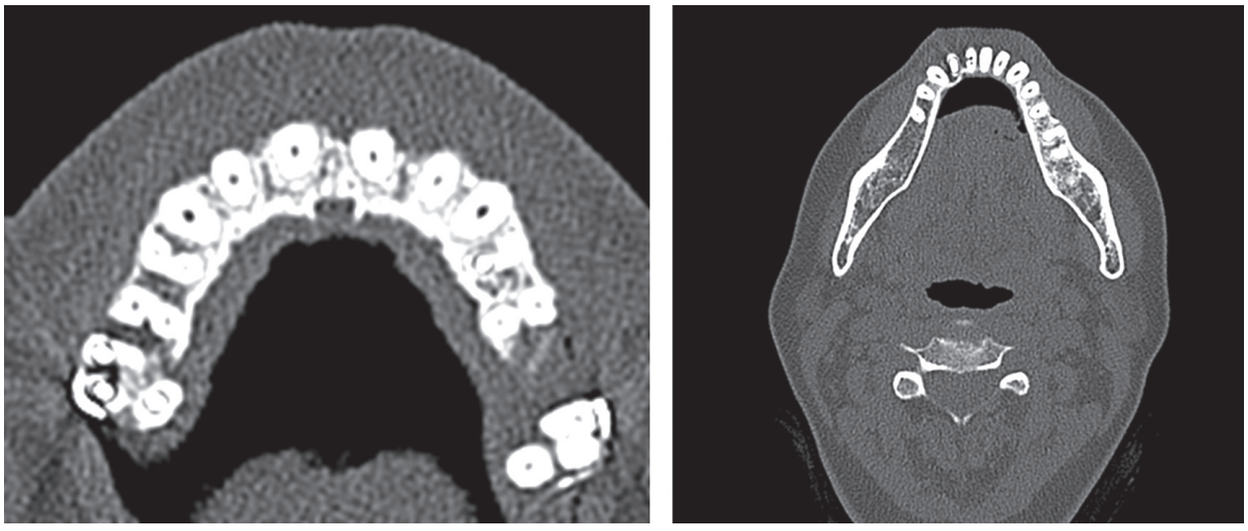

Fig. 9.1 Root canal filling seen on right maxillary first molar and mandibular canine

Fig. 9.2 Extend of carious lesion

Fig. 9.4 Periapical infection leading to loss of labial cortical plate

Fig. 9.3 Periapical infection leading to maxillary sinus infection

are also prone to secondary canals. Maxillary first premolars, which generally have two canals, have three canals 5 to 6 percent of the time. Twenty-four percent of maxillary second premolars have second root canals and occasionally three canals. Mandibular premolars are notorious for having extra canals 26.5 percent in first premolars and 13.5 percent in second premolars. Almost one-third of all mandibular lateral incisors have two canals with two foramina. Study conducted by Rathi et al (2010) revealed presence of mesiobuccal canal (MB2) in the age group of 51 to 60 years (29.50%), followed by 31 to 40 years and 21 to 30 years. (19.67%), 41 to 50 years (16.39%), 61 to 70 years (8.19%), 10 to 20 years (6.55%).

The highest distolingual canal incidence was detected of 21 to 30 years (52.63%), followed by 41 to 50 years (15.78%), 10 to 20 years and 31 to 40 years (10.52%), 51 to 60 years (5.26%) **(Figs 9.8 to 9.14)**.

Intraoral radiographs are a two dimensional imaging modality of a three dimensional structure. Hence anatomy in the third dimension cannot be assessed on radiographs. Because root canals tend to lie one behind the other in buccolingual plane, they get superimposed onto each other on periapical panoramic radiographs

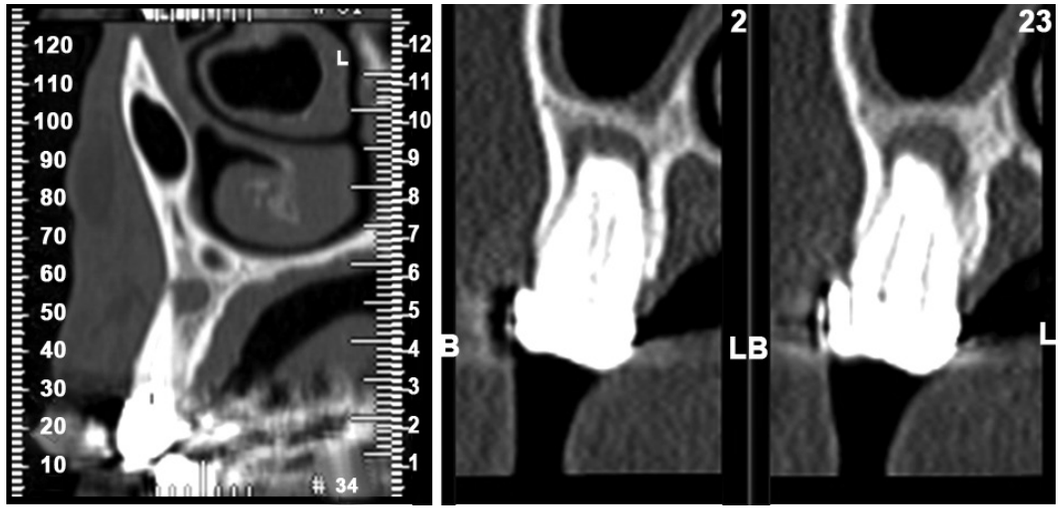

Fig. 9.5 Periapical granuloma seen on dental CT

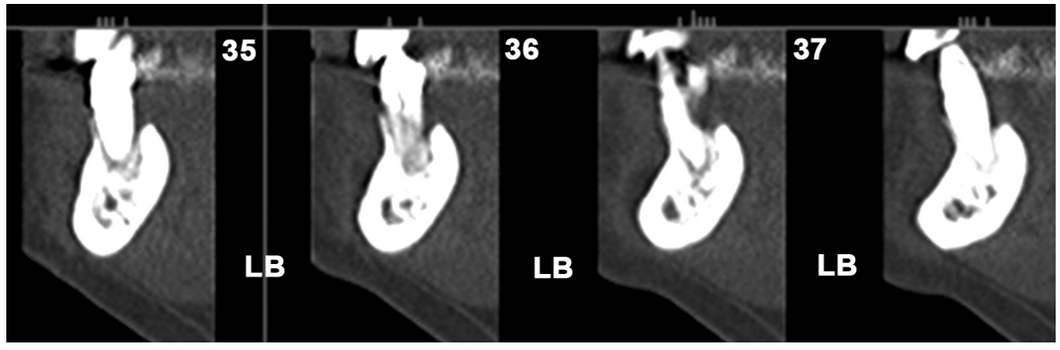

Fig. 9.6 Perio endo lesion

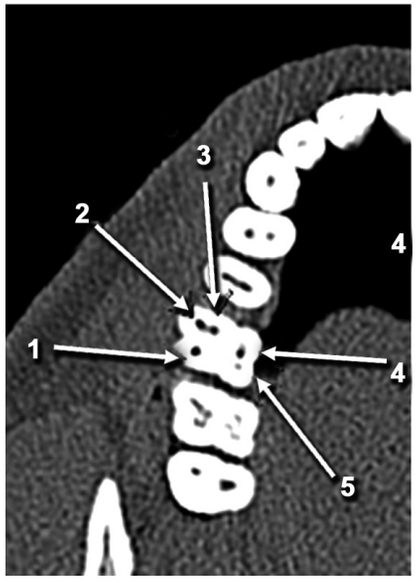

Fig. 9.7 Extra canals in right maxillary molars

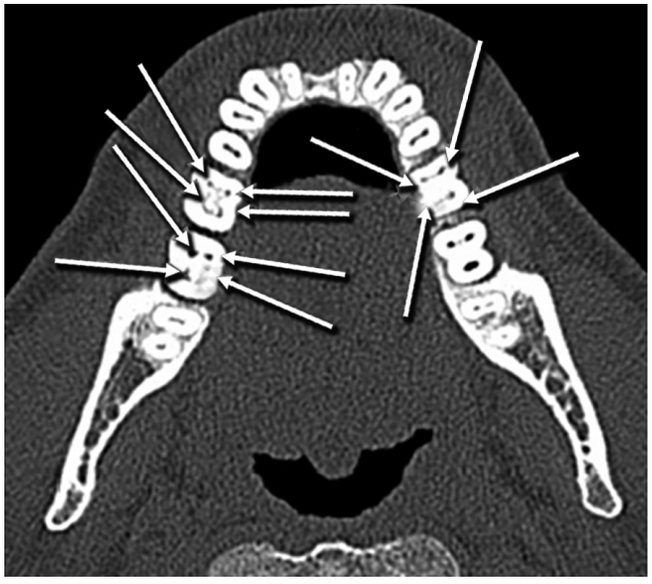

Fig. 9.8 Axial image showing two canals in mandibular left lateral incisor, and four canals in right and left first molar

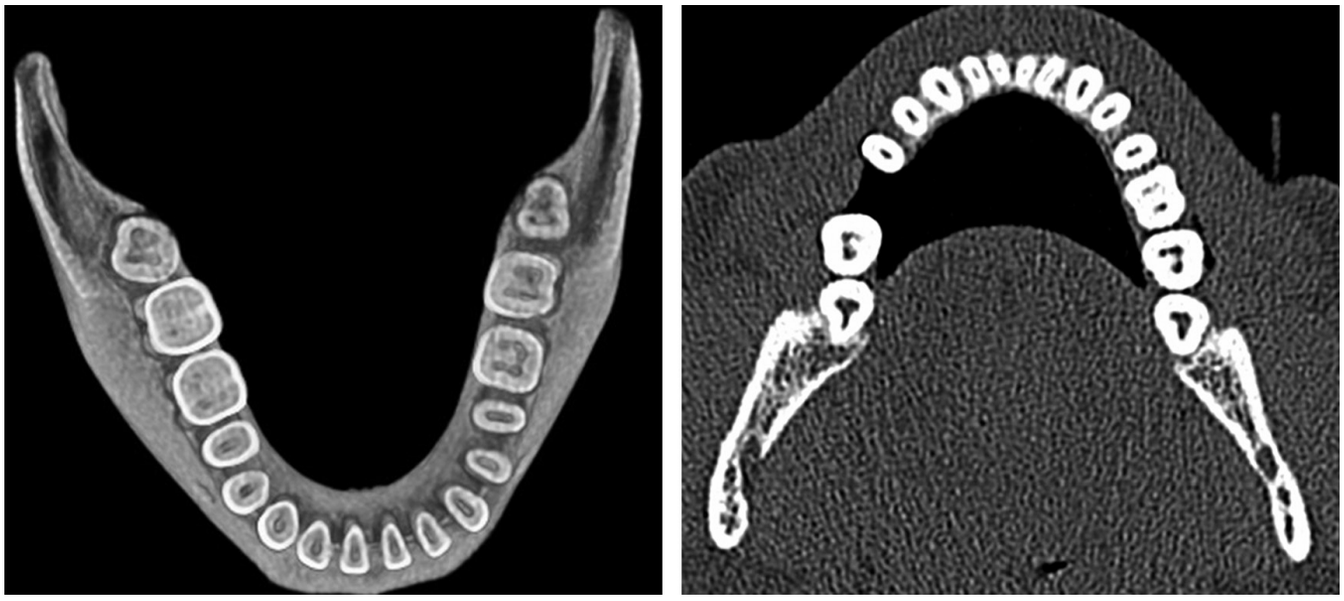

Fig. 9.9 C-Shaped root canal anatomy seen with left mandibular first molar

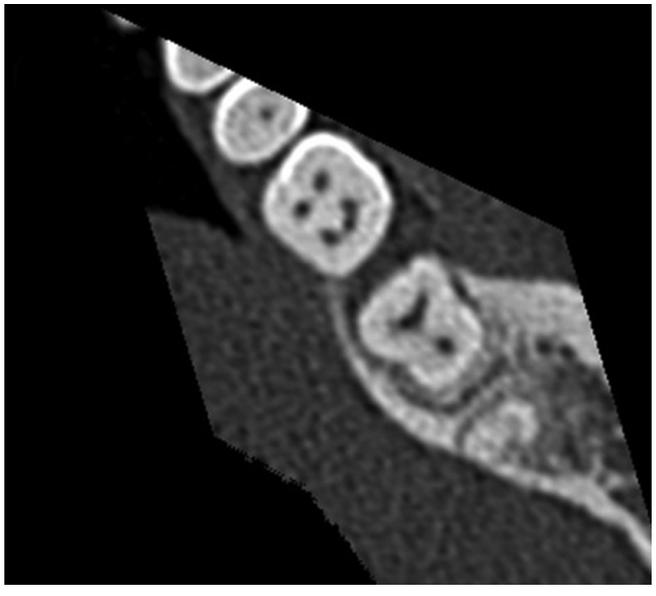

Fig. 9.10 Extra canal seen in lower molar

Fig. 9.11 Classic appearance of four canals in mandibular right first molar

and easily go undetected. According to Robinson et al on dental CT a groove can be observed as a radiolucent longitudinal line within the root parallel to periodontal ligament, suggestive of an extra root canal.

Nakata et al. used dental CT to study few cases and found that presence and expansion of periapical lesions in the mesial buccal root and the palatal root of the maxillary right first molar. It also revealed the resorption of the palatal cortical bone **(Fig. 9.5)**. Another case revealed the connection of the apex of the palatal root of the maxillary left first molar and the maxillary sinus. Hyperplasia of mucosa in the maxillary sinus was observed leading to odontogenic maxillary sinusitis. Similarly, inflammatory disease is seen well on dental

Fig. 9.12 Extra palatal canal see with maxillary right first molar

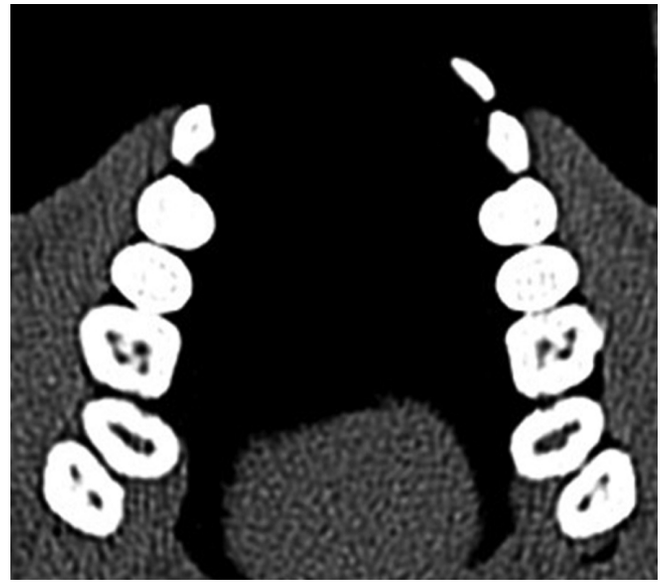

Fig. 9.14 MB2 canals in both molars

Fig. 9.13 MB2 canal in maxillary right second molar

CT than with plain radiography **(Fig. 9.6)**. Plain dental radiographs are still the standard for routine dental evaluation. They are readily available and relatively inexpensive and have better spatial resolution than CT scan. But in complicated cases where there is variation in root canal morphology dentascan could be a useful tool. Limitations of dental CT is the cost factor and radiation dose. With further advancement in radiology and cone-beam computed tomography evolving rapidly and providing three dimensional images at a less radiation dose, this could be the next diagnostic aid in endodontics may be surpassing the conventional radiological tools.

Computed tomography examination to differentiate between periapical cysts and granulomas in teeth with large periapical lesions was studied. It was stated that grey scale value measurements of periapical lesions on CT images were able to differentiate solid (granulomas) from cystic or cavity (cyst) type lesions. It was concluded that Dental CT/CBCT may be clinically more accurate and more useful than biopsy. If confirmed, these findings may influence the decision-making process when considering a non-surgical or surgical approach to endodontic retreatment.

Both medical CT and CBCT have already been used for the planning of periradicular endodontic surgery (Velvart et al. 2001, Rigolone et al. 2003). Three-dimensional imaging allows the anatomical relationship of the root apices to important neighboring anatomical structures such as the inferior dental canal, mental foramen and maxillary sinus to be clearly identified. Velvart et al. (2001) found that the relationship of the inferior dental canal to the root apicies could be determined in every case when using medical CT, but in less than 40 percent of cases when using conventional radiography. It is likely that similar results could be achieved with CBCT using considerably less radiation.

Rigolone et al. (2003) concluded that CT may play an important role in periapical microsurgery of palatal roots of maxillary first molars. The distance between the cortical plate and the palatal root apex could be measured, and the presence or absence of the maxillary sinus between the roots could be assessed. In addition, the thickness of the cortical plate, the cancellous bone pattern, fenestrations, the shape of the maxilla and mandible as well as the inclination of the roots of teeth planned for periapical surgery should be able to be determined before starting surgery (Nakata et al. 2006).

CBCT may also prove useful in the diagnosis of dentoalveolar trauma, because the exact nature and severity of alveolar and luxation injuries can be assessed from just onescan. It has been reported that CT has been used to detect a horizontal root fracture (Terakado et al. 2000). The same fracture may have needed multiple periapical radiographs taken at several different angles to be detected and even then may not have been visualized.

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Chapter 10

Advances in Implant Imaging

Prashant P Jaju, Prashant V Suvarna

As enter this new millennium, technological advancement is at its rapid best. Then how can dental radiological imaging lack behind this advancing phase. The primary concern with dental CT was comparative high radiation dose with respect to plain radiography. This has been overcome with the introduction of cone beam computed tomography (CBCT) and utilization of magnetic resonance imaging (MRI) in implant imaging.

CONE-BEAM COMPUTED TOMOGRAPHY IN IMPLANT IMAGING

Cone-beam computed tomography (CBCT) was introduced in dental field 10 years ago and its evolution is linked to a new paradigm in maxillofacial diagnosis called interactive diagnostic imaging. Foundations of CBCT is related to multiplanar imaging/reformation as observed in dental CT. CBCT provides the advantage of reconstruction of various images in any plane, i.e. coronal, axial, sagittal throughout the volume. If the user desires a panoramic image from the volumetric data, this can be accomplished by carefully selecting with a help of cursor, an uninterrupted sequence of voxels along a curved plane in the maxilla or mandible. The resulting image is a reflection of the voxels in the selected plane. If the operator selects the surface only voxels to be displayed, then a 3-D view is produced. CBCT allows interactive diagnosis because the operator could now control the retrieval of diagnostic information. This has promoted interactive diagnosis whereby the user can access much more information about each patient.

CBCT has a conical shaped beam, with an adjustable width. The attenuated X-ray energy is acquired by a single detector with only one revolution around the patient's head. The collected data is converted to shades of gray as is seen in CT. The primary difference between CT and CBCT in terms of acquisition process is that the imaging data are acquired from the entire volume at once in CBCT, instead of stacks of slices as occurs in CT. The Food and Drug Administration (FDA) approved the first CBCT unit for dental use in the United States on march 8, 2001-the NewTom DVT 9000 (Quantitative Radiology srl, Verona, Italy). FDA approval for three more CBCT units quickly followed in 2003 followed for the 3-D Accuitomo, (J Morita Mfg. Corp., Kyoto, Japan) on march 6, the i-CAT (Imaging Sciences International, Hatfield, PA) on october 2, and the CB Mercuray (Hitachi, Medical Corp., Kashiwa-shi, Chibaken, Japan) on october 20. Since 2003, a number of other CBCT units have been FDA approved in the United States, including the Kodak 9000 3-D, (Carestream/trophy, marne-la-vallée, France), which is currently the highest resolution unit. Once the reformatted images are available, a series of interactive applications are at operator's disposal,including measurement tools as seen with dental CT. Scientific studies and research have established the facts that available bone measurements are accurate (life size) with most of CBCT scanners currently in the marked. Estimated error in various diagnostic tests involving accuracy of measurements with different CBCT scanners was reported to be between 5 to 12 percent.

Perhaps the greatest practical advantage of CBCT in maxillofacial imaging is the ability it provides to interact with the data and generate images replicating those commonly used in clinical practice. All proprietary software is capable of various real-time advanced image display techniques, easily derived from the volumetric data set. These techniques and their specific clinical applications include:

- ***Oblique planar reformation:*** This technique creates nonaxial 2D images by transecting a set or "stack" of axial images. This mode is particularly useful for evaluating specific structures (e.g., TMJ, impacted third molars) as certain features may not be readily apparent on perpendicular MPR images.
- ***Curved planar reformation:*** This is a type of multiplanar reformation. accomplished by aligning the long axis of the imaging plane with a specific anatomic structure. This mode is useful in displaying the dental arch, providing familiar panorama like thin-slice images. Images are undistorted so that measurements and angulations made from them have minimal error.
- ***Serial transplanar reformation:*** This technique produces a series of stacked sequential cross-sectional images orthogonal to the oblique or curved planar reformation. Images are usually thin slices (e.g. 1 mm thick) of known separation (e.g. 1 mm apart). Resultant images are useful in the assessment of specific morphologic features such as alveolar bone height and width for implant site assessment, the inferior alveolar canal in relation to impacted mandibular molars, condylar surface and shape in the symptomatic TMJ or evaluation of pathological conditions affecting the jaws.
- ***Multiplanar volume reformations:*** Any multiplanar image can be "thickened" by increasing the number of adjacent voxels included in the slice. This creates an image that represents a specific volume of the patient. The simplest technique is adding the absorption values of adjacent voxels, to produce a "ray sum" image. This mode can be used to generate simulated panoramic images by increasing the slice thickness of curved planar reformatted images along the dental arch to 25 to 30 mm, comparable to the in focus image layer of panoramic radiographs.

Added feature with CBCT software is definition of path of inferior alveolar nerve in the mandibular canal, and evaluated in relation to the planned position of dental implants.

With respect to measurement of bone density at implant site, CBCT does not perform exceedingly well in comparison to dental CT. This is mainly due to the high level of noise in the acquired images. Slight inconsistencies in the sensitivity of the CBCT detector in capturing the attenuated X-ray energies may also contribute to inaccuracies in bone density estimation. Data acquired from CBCT is generally dicom compliant, but in cases of lack of dicom compatibility, data is converted into a viewable format, i.e. Simplant (Materialize Dental NV, Leuven Belgium). Once the conversion is complete, a wide range of dental implant planning tools combined with realistic and undistorted views of the maxillofacial skeleton and the soft tissues is available. Diagnostic and planning software are available to assist in orthodontic assessment and analysis (e.g. Dolphin 3D, Dolphin Imaging, Chatsworth, California) and in implant planning to fabricate surgical models (e.g. Biomedical Modeling Inc., Boston, Massachusetts); to facilitate virtual implant placement; to create diagnostic and surgical implant guidance stents (e.g. Virtual Implant Placement, Implant Logic Systems, Cedarhurst, New York; Simplant, Materialise, Leuven, Belgium; EasyGuide, Keystone Dental, Burlington, Massachusetts); and even to assist in the computer-aided design and manufacture of implant prosthetics (NobelGuide/Procera software, Nobel Care AG, Goteborg, Sweden). Software is also available to provide surgical simulations for osteotomies and distraction osteogenesis (Maxilim, Medicim NV, Mechelen, Belgium). This area is a blossoming field that provides opportunities for practitioners to combine CBCT diagnosis and 3D simulations with virtual surgery and computer-assisted design and manufacture. Image guidance is an exciting advance that will undoubtedly have a substantial impact on dentistry.

As with all technology, CBCT has limitations. The patient must be motionless during the scanning to achieve a good image; otherwise the image may display streaking. There also will be artifacts in the image around metal prostheses, making it difficult to evaluate teeth with metal restorations.

Furthermore, the larger FOV systems can image tissues with which the dentist is not familiar, but might be held responsible for interpreting. It is often prudent to refer such image volumes for evaluation by a specialist in oral and maxillofacial radiology.

MAGNETIC RESONANCE IMAGING (MRI)

MRI does not use ionizing radiation. MRI is based on the phenomenon of nuclear magnetic resonance (NMR) which was first described independently by two groups of workers in the USA. MRI was not originally thought of as a useful modality for preimplant assessment, but the use of appropriate sequences and parameters allows us largely to overcome the perceived difficulties. For

preimplant assessment, as normal anatomy is being examined, the use of T_1-weighted sequences, as external cortical plates appears black.This MRI is due to the very low signal owing to the absence of water or lipid protons. In contrast, the more organic cancellous bone appears very bright in T_1-weighted images, as a result of the signal from protons in the fatty bone marrow,unlike the grey radiological appearance of this tissue. Neurovascular channels such as inferior dental canal and the nasopalatine foramen are identified as discrete dark structures within the bright cancellous bone. External interface between cortical bone and mucosa is clearly identified on MRI. Recent studies suggest that MRI assessment of maxilla and older patients is difficult. Also there is an initial learning curve,with many clinicians find it difficult to interpret MRI. Also appearance of bone and soft tissue is different on MRI as compared with other radiological studies.

With ever increasing accessibility of MRI, reduction in operating costs and use of non ionizing radiation, can increase the use of MRI in the field of implant dentistry. Also interventional scanners may allow operators with image guided implant surgery.

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Chapter 11

Case Study

CASE 1: EDENTULOUS RIDGE

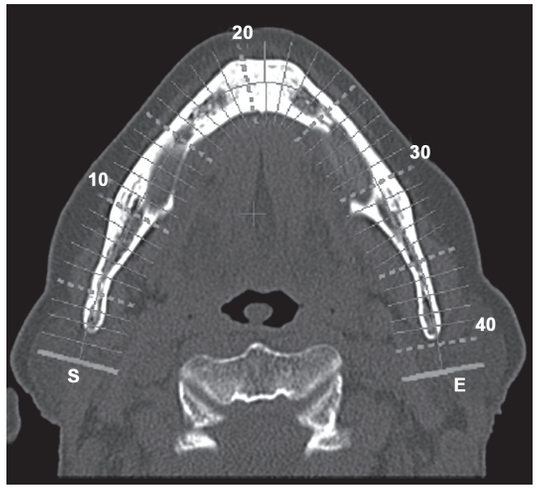


Fig. 11.1 Axial image showing paraxial slices number and implant planned in anterior region

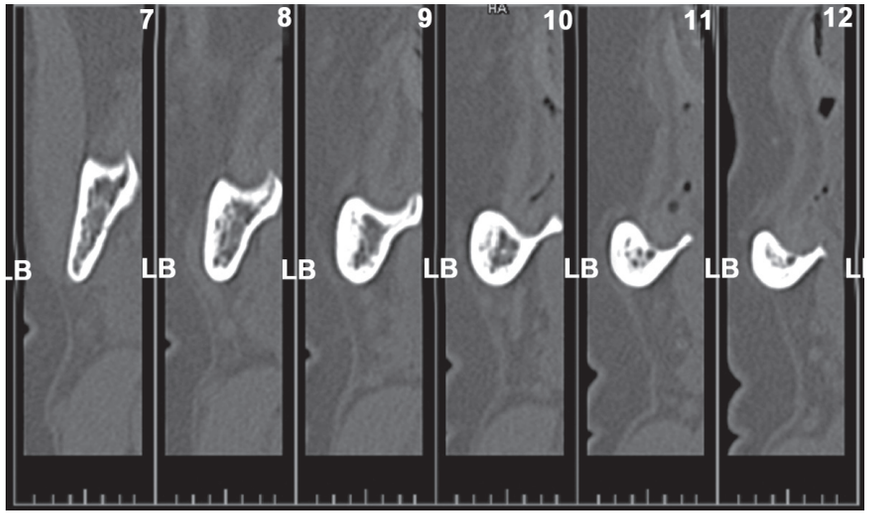


Fig. 11.2 Varied ridge pattern observed

CASE 2: MANDIBULAR SINGLE MOLAR IMPLANT

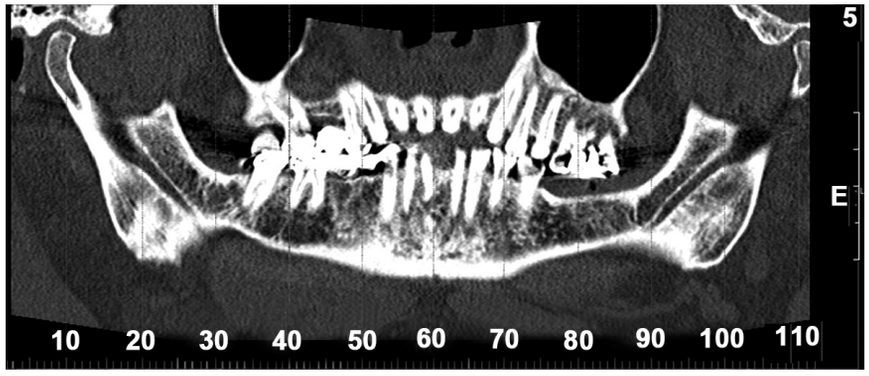


Fig. 11.3 Implant to be placed in mandibular left first molar region

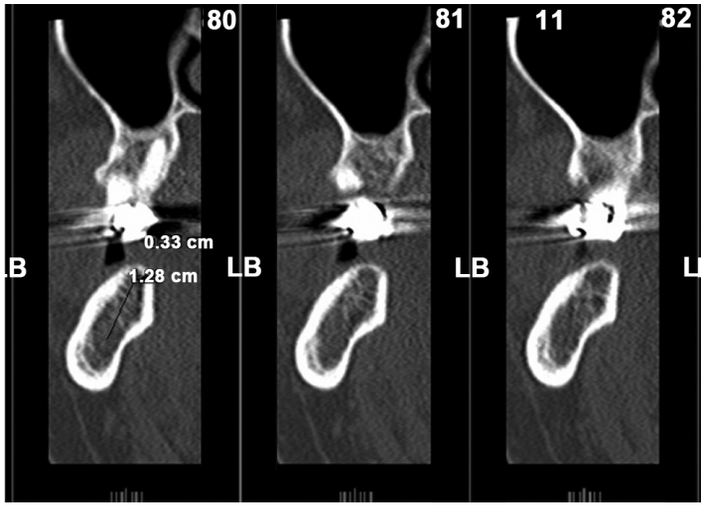


Fig. 11.4 Slice 80 shows measurement of available bone along with concavity in lingual cortical plate

CASE 3: MANDIBULAR SINGLE TOOTH IMPLANT WITH CONCAVITY

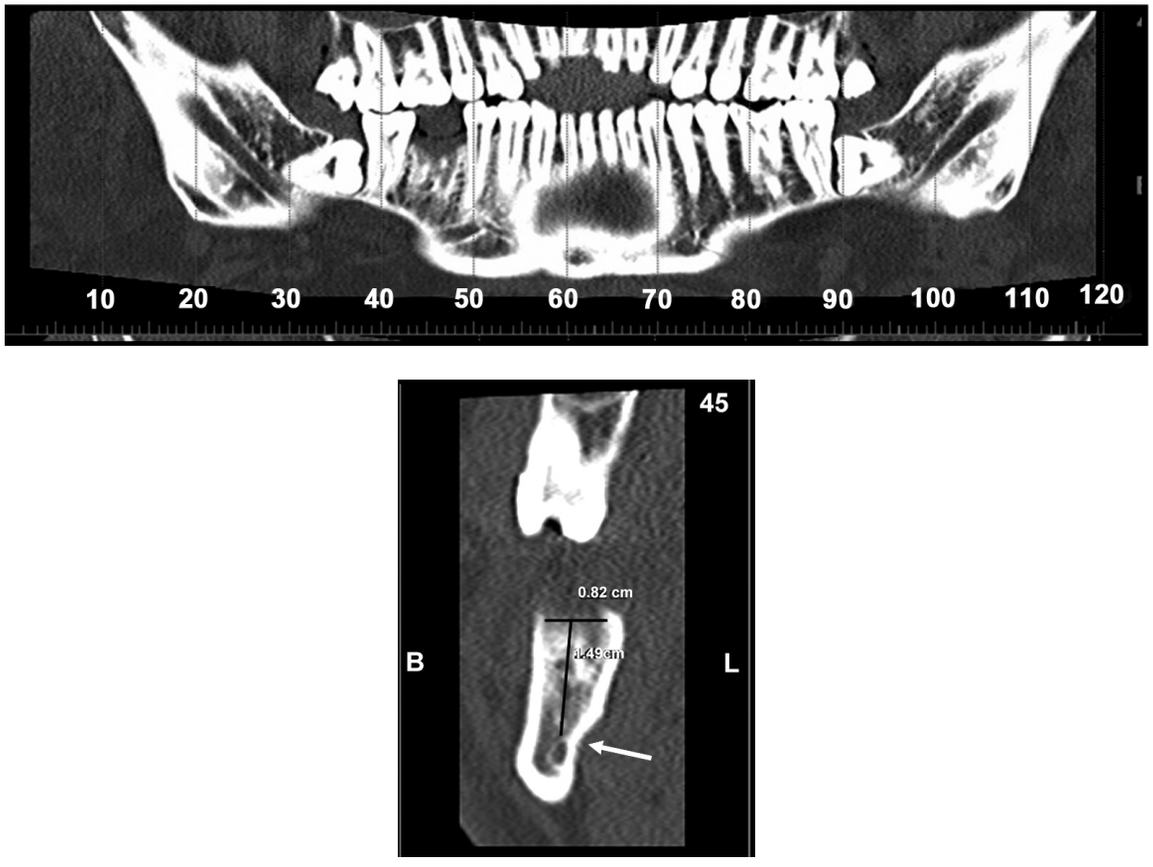


Fig. 11.5 Single tooth implant placement (Slice 45). Note the lingual cortical concavity which is not evident on panoramic image

CASE 4: MAXILLARY ANTERIOR REGION

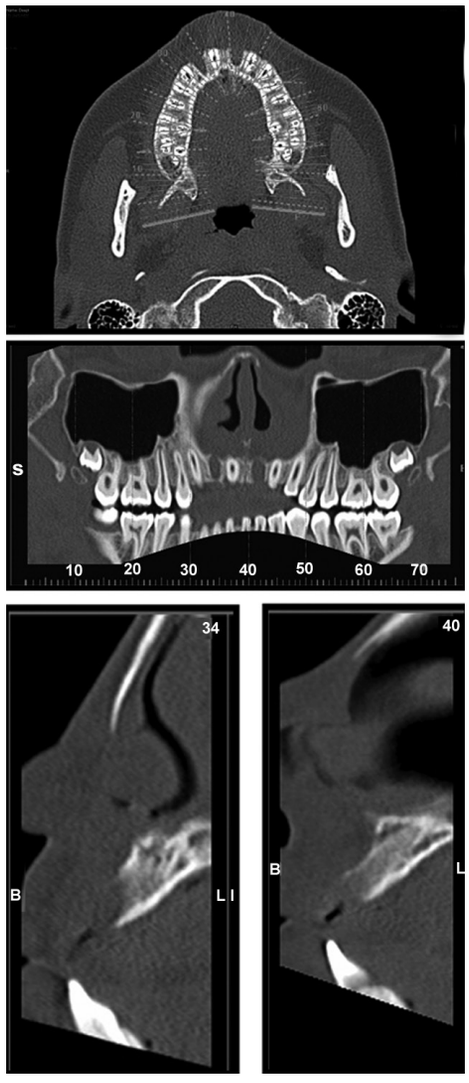


Fig. 11.6 Implant site in maxillary anterior region (Slice 34 and 40)
Note: The loss of labial cortical plate in Slice 34

CASE 5: MAXILLARY ANTERIOR SINGLE REGION IMPLANT

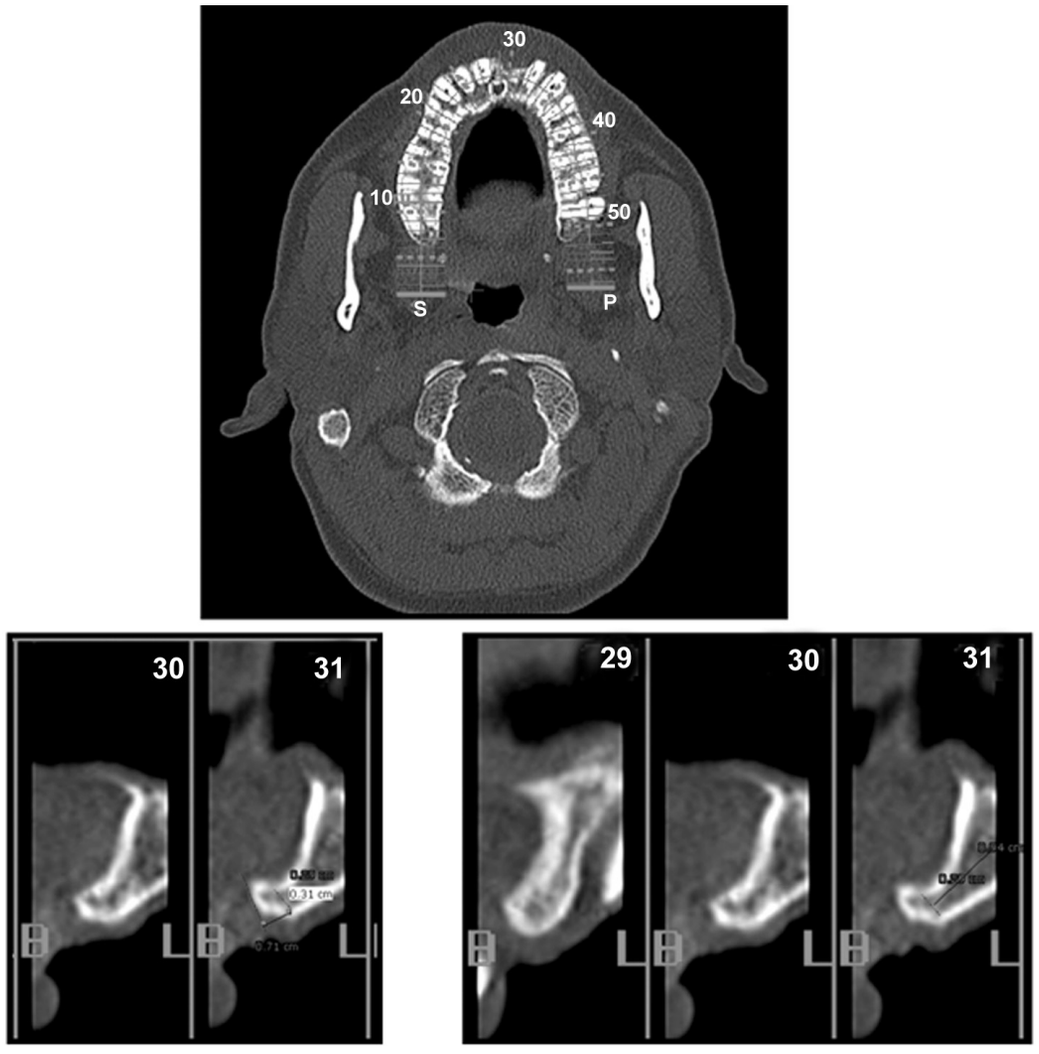


Fig 11.7 Labial concavity seen on paraxial images (Slice 30 and 31). Osteotomy advised before implant placement. Slice 29 shows nasopalatine canal

CASE 6: MAXILLARY MOLAR REGION ESINUS LIFT CASEH

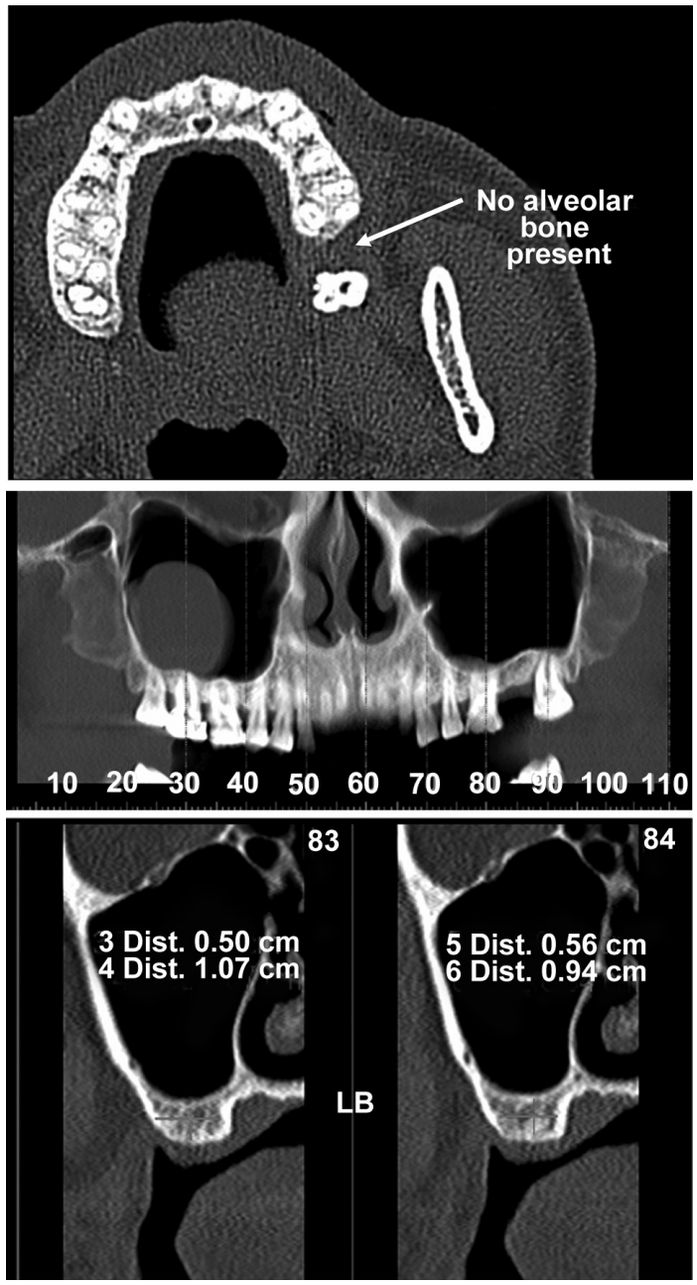


Fig 11.8 Sinus lift procedure required due to lack of sufficient height in left maxillary second molar region(Slice 83–84)

CASE 7: MAXILLARY BILATERAL SINUS LIFT

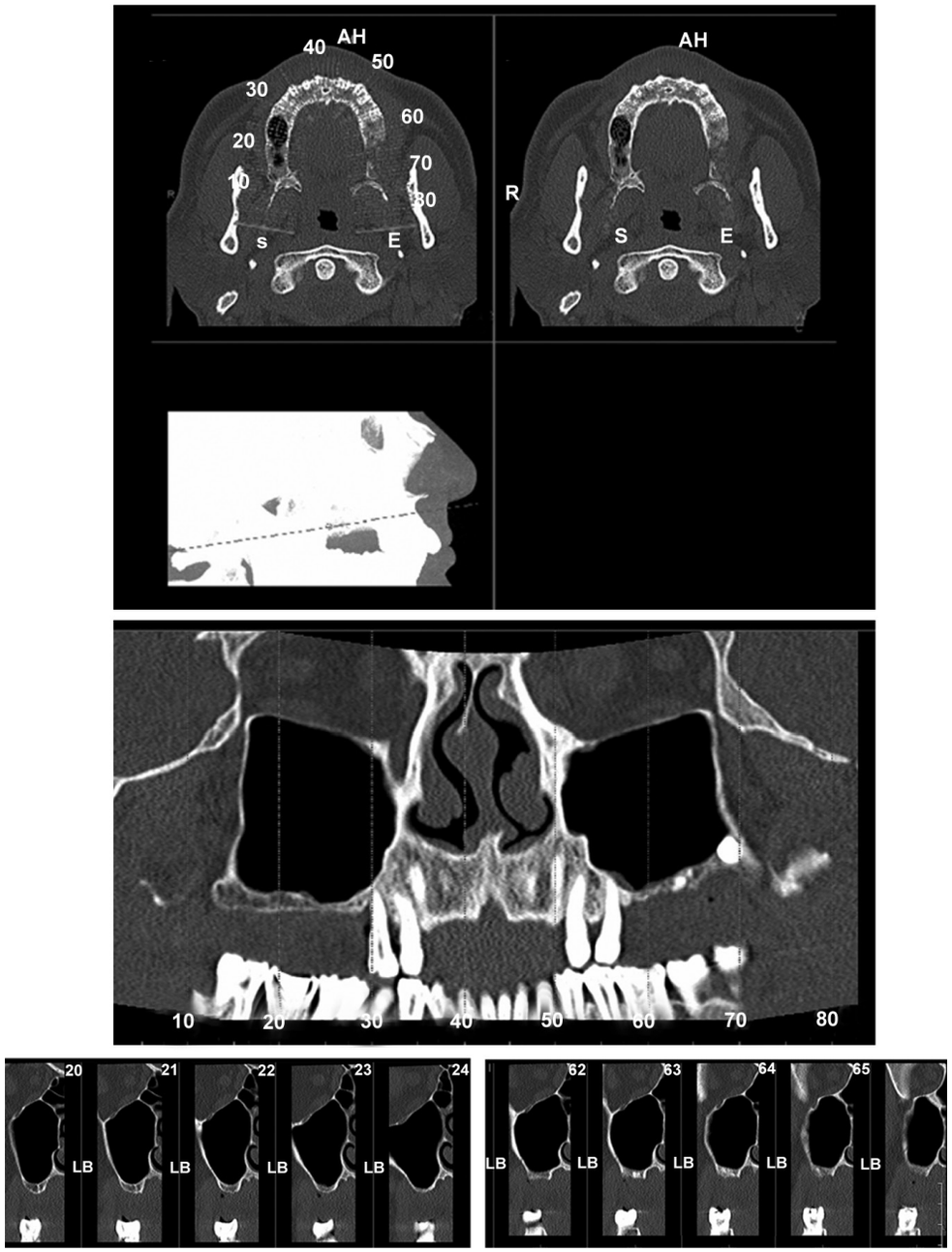
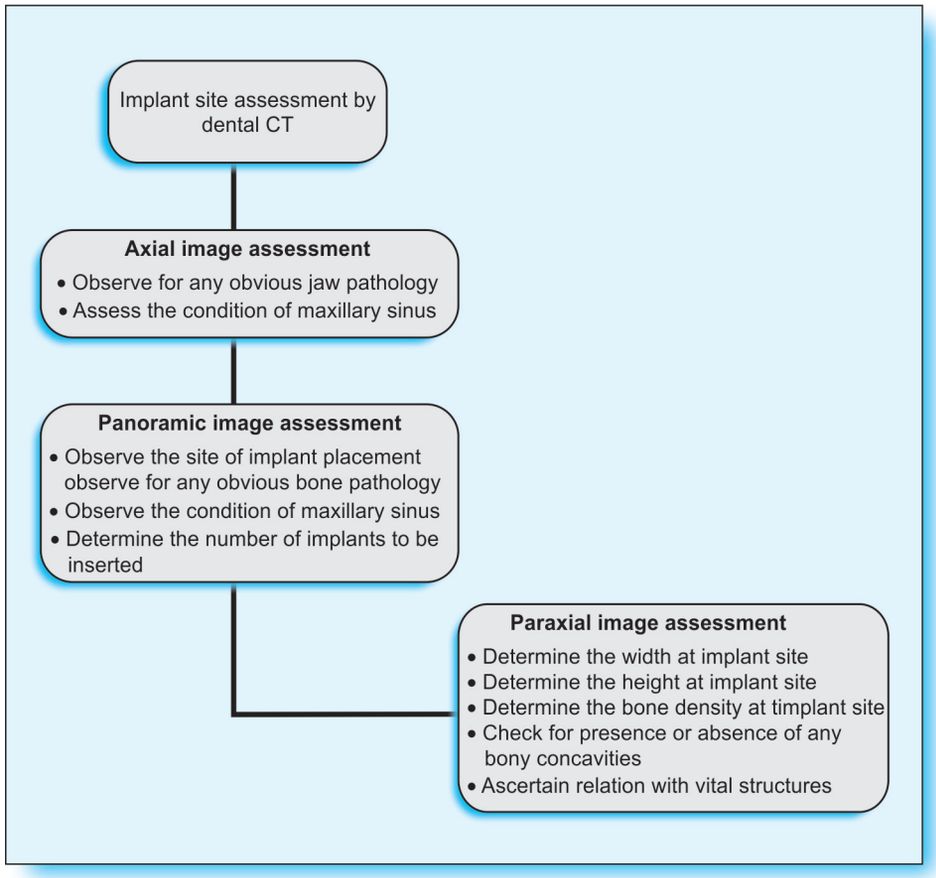


Fig. 11.9 Case of bilateral sinus lift procedure. Insufficient height at implant sites (Slice 20–24; Slice 62–66)

Flow chart 11.1 Assessment of radiographic image on dental CT



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